# ENERGY EFFICIENCY EVALUATION IN A COMMERCIAL BUILDING BY STRATEGIC AUDITING AND DEMAND SIDE MANAGEMENT

A Dissertation submitted in fulfilment of the requirements for the Degree

of

**MASTER OF ENGINEERING**

in

**Power Systems**

Submitted by

**Gagandeep Singh Brar**
**Reg. No.: 801742009**

Under the Guidance of

**Dr. Pawan Kumar**
**Assistant Professor, EIED**

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

**2019**

**Electrical and Instrumentation Engineering Department**
**Thapar Institute of Engineering & Technology, Patiala**
***(Declared as Deemed-to-be-University u/s 3 of the UGC Act., 1956)***
**Post Bag No. 32, Patiala – 147004**
**Punjab (India)**

# DECLARATION

I hereby certify that the work which is presented in dissertation entitled, "**Energy efficiency evaluation in a commercial building by strategic auditing and demand side management**", in partial fulfilment of the requirements for the award of the degree of Master of Engineering in Power Systems, submitted to Electrical & Instrumentation Engineering Department of Thapar Institute of Engineering & Technology (Deemed to be University) is as authentic record of my own work carried under the supervision of Dr. Pawan Kumar. It refers others researcher's work which are duly listed in the reference section. The matter contained in this dissertation has not been submitted, neither in part nor in full to any other degree to any other university or institute except as reported in text and references.

Gagandeep Singh Brar

Place: TIET, Patiala **(Gagandeep Singh Brar)**

Date: 15-07-2019 **Roll No.: 801742009**

It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

**(Dr. Pawan Kumar)**

Date: 15-07-2019 **Assistant Professor**

Electrical & Instrumentation Engineering Department

Thapar Institute of Engineering & Technology, Patiala

ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to my supervisor Dr. Pawan Kumar, Assistant Professor, Thapar Institute of Engineering & Technology, Patiala, Punjab for his guidance, support and encouragement in steering this thesis work. I feel privileged to have been associated with him as my project supervisor.

I would like to thank Prof. R.S. Kaler, Head, Electrical and Instrumentation Engineering Department, Thapar Institute of Engineering & Technology, Patiala, Punjab for permitting to pursue this work.

Also I would also like to thank all the faculty members of Electrical & Instrumentation Engineering Department, Patiala and my batch mates for their unconditional support for the completion of this thesis work.

**GAGANDEEP SINGH BRAR**

**(801742009)**

# TABLE OF CONTENTS

# TABLE OF CONTENTS (Continued)

## TABLE OF CONTENTS (Continued)

# LIST OF TABLES

## LIST OF TABLES (Continued)

# LIST OF FIGURES

# NOMENCLATURE

| | |
|---|---|
| P | Power (Watts) |
| V | Voltage (V) |
| I | Current (A) |
| Ø | Luminous Flux (lm) |
| E | Illuminance (lux) |
| K | Luminous Efficacy (lm/W) |
| L | Length of space (m) |
| W | Width of space (m) |
| H | Height of space (m) |
| A | Area ($\boldsymbol{m^2}$) |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| DSM | Demand side management |
| DR | Demand response |
| DER | Distributed energy resources |
| PAR | Peak-to-Average ratio |
| HEM | Home energy management |
| TOU | Time of use |
| TOD | Time of day |
| DSO | Distribution system operator |
| EER | Energy efficiency ratio |
| AC | Air conditioner |
| TR | Tons of refrigeration |
| COP | Coefficient of performance |
| ILE | Installed load efficacy |
| ILER | Installed load efficacy ratio |
| LED | Light emitting diode |
| CFL | Compact fluorescent lamp |
| LVAC | Light ventilation and air conditioning |
| CFM | Cubic feet per minute |
| RPM | Revolutions per minute |
| EA | Energy auditing |
| RI | Room index |

| | |
|---|---|
| RCR | Room cavity ratio |
| TLE | Target load efficacy |
| UF | Utilization factor |
| IMP | Illuminance measurement points |
| DR | Diversity ratio |
| SR | Strength ratio |
| LI | Luminous intensity |
| ECTT | Total energy consumption |
| ECLT | Total energy consumption of lights |
| ECAC | Total energy consumption of all ACs |
| ECFT | Total energy consumption of all fans |
| ECWDSM | Energy consumption without DSM |

# ABSTRACT

In the ever-growing demand scenario, energy efficiency in the commercial and residential buildings has gained momentum in the recent years. At distribution level, the important function of energy management system are considered as,

1. Strategic Energy Auditing (EA)
2. Demand Side Management (DSM)

Energy auditing (EA) is the cost effective means to identify the requirements of power components and their operation. This is due to the fact that in a commercial and residential building the major components are lighting source and heating, ventilating and air conditioning. The number of these components, to be installed, depends upon the area covered and the operating requirements like minimum lumens, air circulation in cubic feet per minute and the temperature level. In this scenario, EA allows identifying the methods, scope and time for energy management and helps the costumers to manage their energy consumption wisely in order to reduce their energy bills.

In addition, the reduction in energy consumption reduces the carbon emission level and it leads to increase in sustainability of smart grid. However, most of the traditional strategies employ specific system techniques & algorithms whereas in recent years load shifting based DSM techniques have been used for the futuristic smart grid applications. In the commercial and residential buildings, the power consumption mainly depends upon the number of persons involved, surrounding temperature & humidity and the luminous intensity due to sun light. Considering the above fact, this work represents the review of different DSM techniques and the methodologies to achieve the desired objective of cost minimization under different operating scenario. The energy data of three month, in a year, is collected under three different seasonal changes i.e. January (severe cold), April (moderate) and August (severe hot). This gives a clear picture of variation in load demand under moderate, comfort and severe environmental conditions. The energy data under these three conditions are averaged and the DSM schemes are developed for the operation of power components before energy auditing and after energy auditing. Moreover, the performance of the proposed DSM techniques is compared with the practical results in both scenario and from the results it has been observed that the energy consumption has reduced significantly, in the proposed DSM approach.

# CHAPTER 1
# INTRODUCTION

## 1.1 Overview

Presently, the energy cost has increased at an alarming rate. A surveys conducted by various agencies, shown that there is 10% to 30% potential to save energy in secondary power distribution. Energy efficiency has been the first priority for any organization to become more cost effective & its basic objective. The secondary power distribution can be divided into three types of loads–residential, industrial &commercial. Residential loads are managed through demand response, whereas industrial loads are voltage profile dependent & commercial load depend upon social, environmental and technical factors.

Several works in the field of load management is done & authors have given various algorithms for load shifting for reduction in load demand in smart grid scenario. DSM has been employed for controlling energy consumption which permits integration, easy maintenance and up-gradation in commercial buildings. It has been observed that operational and technical factors directly affect the efficiency of framework developed .For the intensification of energy efficiency, all social, environmental &technical factors simultaneous are imposed. To demonstrate effectives of proposed approach practice result are compared with proposed results for commercial organization

Energy management is one of the concerning issue in present days. Lots of studies and algorithms have been developed to do the work of energy management efficiently. Energy efficiency generally means to reduce the energy consumption of the customer. The reduced energy consumption will lead to enhance energy efficiency. The energy management is carried out for residential, commercial & industrial customers. The energy management is carried out with the help of various strategies like DR, DSM, DER etc number of algorithms have been developed to enhance energy efficiency of customer. HEM is the commonly used algorithm. Energy management not only tells the profile of loads like illuminance level, wattage, room area etc which are useful and are being wasted but it also gives the recommendations to the customers which not only helps to increase in energy efficiency but it also reduce their energy bills. Incentives are also provided to the customers so that they can consume less energy and are being penalized if they violate it.

This prevents the fluctuation and interruptions of power supply and it also helps to prevent overloading.

### 1.2 Literature Review

With recent development in DSM technologies in secondary distribution system the reduction in the energy consumption is the prime motive of the research due to depletion of conventional energy resources. Researchers have presented an extensive work for improvement in energy efficiency in order to reduce the operating cost simultaneously. However, the objective functions developed by different researchers may differ from each other depending upon the operating constraints and requirements. The research work presented in the past has been reviewed in this thesis and it is discussed as follows;

Logenthiran *et al*. [1] has developed a heuristic optimisation technique for the reduction of peak demand in smart grid based on demand side management in presence of various loads are like residential, commercial and industrial loads. Manisa *et al*. [2] conferred that DSM plays an important role in smart grid functionalities in various areas such as electricity market control& management and management of decentralised energy when number of devices available for control is more. AHM–Rad *et a*l. [3] has developed the DSM scheme which leads to reduce the peak-to –average ratio (PAR), energy cost& each user's daily electricity charges. Palensky *et al*.[4] observed that with the rise in technology generation is not a problem but grid capacity is a major concern. Therefore, DSM helps to overcome from this problem. Here, authors have categorized the DSM into energy efficiency, time of use, DR, spinning reserve. Costanzo *et al*. [5] revealed that the estimated power consumption in worldwide buildings leads to approximately 40% of global energy consumption.

Agnetis *et al*.[6] emphasis on the reduction of greenhouse effect through dynamic DSM. Authors have developed a heuristic algorithm for real time application but it has the limitation of computational power & memory size. Conversely, Zhao *et al*. [7] presented DSM for residential loads in order to improve power quality and reliability of supplying power. For this objective, DR comes into picture which changes residential electricity demand according to the variations in the electricity prices. Utility companies will also get the benefit by the reduction of PAR which leads to increase in stability of entire electrical system. Safdarian *et al*. [8] analysed that knowledge of DR capability is a prime perspective of DSM and researchers have given much attention on it for energy consumption & saving the cost of electricity bills.

Kuzlu *et a*l [9] forecasted that in upcoming decades the world energy consumption is expected to rise by 53% at the rate of 2.3% per year from now to 2035. It would be the reason for cascading failure and hence blackouts. Here, authors have developed a cost-effective home energy management (HEM) system. Further, Mondal *et a*l.[10] observed that DSM is the important feature in a smart grid as it gives opportunity for flexible energy demand. Abdelwahad *et al.*[ 11] have developed new schemes like real time pricing, shift load peak by scheduling power for home energy management. Conversely, Tsagarakis *et al.*[ 12] revealed that the electricity cost not only consist price of electricity but also includes environmental cost. Authors in [13]-[15] observed that the commercial, residential buildings and industrial are great source for DR because of their massive consumption respectively. They proposed new schemes for improvement of energy efficiency.

However, authors in [16] observed that the integration of distributed energy resources (DER) reduced the difference between maximum and they proposed DSM for minimization of energy consumption. Authors in [17] have introduced the coordinated optimization for centralised & distributed DSM frameworks, because DSM has a problem that user flexibility varies over time. But, in [18] it has been observed that the implementation of DSM is the biggest concern therefore, authors in [19] focused on the DR and suggested DSM schemes based on market scenario. Further, in [20] the DSM is proposed based on time of use in order to reduce the peak demand of residential loads. On the other hand, Piette et al. [21] presented the DSM strategies for commercial buildings for same objective. Similarly, authors in [22] presented a case study for residential building using PSO whereas, in [23] DSM is emphasized to reduce the additional energy &new generation infrastructure. Chu *et al*. [24]found that DSM is very effective when load sharing and time of unit is considered, if the cost of fuel is not the concern. In [25], an advanced control and energy information system is suggested for DSM.

Zhou *et al*. [26]conferred that DSM technology is very useful in the scenario of high variability of loads for the improvement of energy efficiency and the reliability. Gellings *et al.* [27]implemented the DSM for the futuristic consumer demand for electricity. Qureshi *et al*. [28] has presented co-ordination of DSM techniques with phase change material including real time pricing. Nguyen *et al*. [29] has presented DSM in presence of the storage devices and authors have developed an proximal decomposition algorithm to achieve their objective. Handa *et al*. [30] has emphasized the need to address the environment concern in the objective formulation. Du *et al*. [31] presented the DSM algorithm for thermostatically controlled house appliances and emphasized on the minimum payment or maximum comfort. Similarly in [32] DSM impacts on probabilistic load and energy is considered to study the impact of DSM on capacity requirements. But, in [33] along with energy consumption the maximization of expected social welfare is also presented whereas, authors in [34] have developed incentive schemes to manage the energy consumption.

**Table 1.1: Objective and constraints for DSM based optimization function**

| Ref | Objective | Constraints |
|---|---|---|
| [5] | $\sum_{i,j} F_{ij}\, x_{ij} + \sum_{i,j} G_{ij}\, d_{ij}$<br>The objective is formulated for minimization of the cost | $\sum_i P_{ixij} \leq C_j, \forall j \in M;$ and $\sum_j d_{ij} = 1; \forall_i \in N;$<br>The constraints are applied to total power consumption at each time frame & it should lie in the given capacity limit. |
| [6] | J=$\propto_{EC} \bar{C}_{EC} + \propto_{PR} \bar{C}_{PR} + \propto_{CC} \bar{C}_{CC}$<br>The objective function is for overall energy cost, scheduling performances & climatic comfort. | $\sum_{t=1}^{T} (1 - z_{a,t}) \leq OFF_a^{MAX} and \sum_{\tau=t}^{t+OFF_a^{MAX}-1} z_{a,t} \geq 1;$<br>And $\sum_{\tau=t+1}^{t+ON_a^{MIN}} z_{a,\tau} \geq ON_a^{MIN} (z_{a,t+1} - z_{a,t})$.<br>The constraints are applied to the interruptible loads to limit total number of off slot for interruptible appliances |
| [7] | $W_1 \times \frac{\left(\sum_{u=1}^{120} \widetilde{pr} Cu\, P_{scd}^{(u)}\right) P_{scd}^{(u)}}{\left(\left(\sum_{u=1}^{120} \widetilde{pr} Cu\, P_{scd}^{(u)}\right) P_{scd}^{(u)}\right) max} + W_2 \times \frac{\sum_{a \in A} \rho^{DTR_a}}{\left(\sum_{a \in A} \rho^{DTR_a}\right) max}$<br>The objective of optimisation is to minimise the total power consumption and lowering the delay time rate(DTR) of home appliances. | $t_a \in [\alpha_{a,} \beta_a - l_a]$<br>The constraints are applied such that the value of delay parameter satisfies the number of automatic operated appliances (AOAs). |
| [10] | $\varphi_n(.) = (E_{\max})_n e_n - 1/2 \alpha \frac{(E_{res})_n}{(E_{max})_n} e_{n^2} - \beta \frac{p_m}{p_{min}} S_w e_n$<br>The objective function is formulated for optimal energy demand of the customer including maximum energy storage capacity in order to increase the revenue of the microgrid (utilities). | $[\arg min \sum_{m=1}^{m \in W} G_m \geq \sum_{n=1}^{n \in cW} a_n] and\ [\sum_{m=1}^{m \in W} G_m \geq \sum_{n=1}^{n \in C_w} e_n$ and $S_{w = \left(\sum_{m=1}^{m \in W} G_m - \sum_{n=1}^{n \in C_w} a_n\right)}$ and $\sum_{n=1}^{n \in C_w} x_n \leq S_w$<br>The constraints are applied such that the energy requirement of the customer's appliances & for storage respectively, should be satisfied. |
| [12] | $min \sum_{i=1}^{t} C_{comb} = min \sum_{i=1}^{t} (x. C_{wi} + y. em_{wi}. pen$<br>An problem is formulated to minimise the combined cost using weighted values of the price & GHG emissions. | $E_{new} = E_{old}$<br>$t_{end_{new}} - t_{start_{new}} = t_{end_{old}} - t_{start_{old}}$<br>$P_{max_{new}} < P_{max_{old}}$<br>$P_{max_{new}} - P_{min_{new}} < P_{max_{old}} - P_{min_{old}}$<br>$cyc_{wl} \nexists [T_{peak}]$<br>Constraints are load shifting in order to enforce new aggregate load curve for |

| | | |
|---|---|---|
| | | reduction of peak demand. |
| [14] | $Min: TOC = \sum_{h\in T}\{RTP(h)P_{grid}(h) + \rho_{gas}\ (u_{CHP}(p)g_{CHP}(h) + u_{aux}(h)g_{aux}(h))\}$ To formulate the objective function which deals with the total operation cost (TOC) minimisation. | $P_D(h) = \sum_{K\in M} P_{F,K}(h) + \sum_{l\in N} P_{s,l}\ (h)S_l(h) \le P_{D,}$, $\forall h \in T$ Constraints are applied for the electricity exchanged with power grid & for the natural gas consumption. |
| [14] | $Max: UCCL = \xi_1 \sum_{h\in T}\sum_{i\in N}(\varphi\, ID_i SL_i(h)) + \xi_2 \sum_{h\in T}\gamma CL(h)$ The objective function is formulated for maximising the user's convenience and comfort level. | $P_D(h) = \sum_{K\in M} P_{F,K}(h) + \sum_{l\in N} P_{s,l}\ (h)S_l(h) \le P_{D,}, \forall h \in T$ Constraints are the degree of user's satisfaction in home tasking scheduling & occupant's thermal comfort level. |
| [15] | $\min\sum_{t\in T} P_t^{DA}\, x_t + \mathrm{E}\,[f(x,u,\xi)]$ The objective function comprises the day-ahead electricity purchase cost .This can be done by using two stage stochastic programming. | $u_{it} + u_{it+1}^{On} - u_{it+1}^{off} - u_{it+1} = 0 \forall i \in I, \forall t \in T$ Constraints includes the minimum duration of On/off status which is required to be considered for wear & tear caused by frequent on/off cycle. |
| [17] | $P_u$(I)= $\sum_{t\in T} y_{ut..}bt$ Formulation of Distributed Game –Theoretic framework on payoff function of user u, which coincides with its daily electricity bills. | $y_{ut} = \sum_{a\in A_u}\sum_{n\in N_{au:n\le t}} l_{au}^{u} \cdot x_{au}^{t-n+1}$ The constraints are supplied on the price of electricity with the goal of inducing peak shaving. |
| | Min=$[\sum_{u=1}^{NLD}\sum_{v=1}^{T} P(u,v).*\, t(v) * CE(u,v)] + [\sum_{u=1}^{NLD}\sum_{v=1}^{T} P(u,v) * CD(u,v)]$ The objective function is formulated to minimise the cost of customer electricity bill and peak power reduction in a time frame. | The three main constraints over here are technical, social & environmental. |

In [35] a qualitative analysis of demand response on system reliability is presented. However, in [36] author have presented a coordinated approach for grid, DSM and communication for energy saving. Also, authors in [37] have considered heating, ventilation and air conditioning systems in commercial buildings. Author et al. [38] has developed a DSM paradigm based on stochastic optimization and real time pricing. However, in [39] real time pricing and workload is coupled for DSM. In [40] authors concentrated on potential solutions for implementation of DR under deregulated market scenario and smart grid. However, authors in [41] and [42] have presented an extensive review of the DSM techniques and identify that the programs, issues and approaches relevant to the DSM scheme and their implementations.

Table 1.2 shows the various methods or techniques and the objectives formulated by the researchers for their approaches for DSM. Form this evaluation it can be observed that the load class comprises three load categories namely residential (R), commercial (C) and industrial (I) loads.

**Table 1.2: Objectives and constraints for DSM based optimization function**

| Ref. | Technique used | Objective | Load class | Optimization function |
|---|---|---|---|---|
| [1] | Heuristic approach | To implement future power & integrating advanced sensing technologies | R | Multi objective |
| [2] | Home energy management (HEM) algorithm | To manage high power consumption of household appliances | R | Single objective |
| [3] | Game energy theory | To reduce energy consumption & shifting consumption | R,C | Multi objective |
| [4] | DR based building algorithms | To improve the grid capacity | I | Single objective |
| [5] | Distribution optimisation | To design an autonomous smart building | C, I | Multi objective |
| [6] | Dynamic DSM techniques | To schedule load for Household energy consumption | R | Single objective |
| [7] | Optimal power scheduling | To schedule power for DR | R | Multi objective |
| [8] | DR programs | To study the distribution of network reliability improvements in presence of DR | R, I | Single objective |
| [9] | Score based intelligent HEM technique | To study the impact of HEM operation on customer comfort | R | Single objective |
| [10] | Game theory | To study HEM system with storage in smart grid | R, C | Multi objective |
| [11] | Energy production sustainable models | To study the control of electricity consumption at home | R | Multi objective |
| [12] | Heuristic & Stochastic approach | To access the cost & environmental impacts of residential DSM | R | Multi objective |
| [13] | Transactive market mechanism | To study the control of commercial buildings using DR | C | Multi objective |
| [14] | Mathematical modelling approaches | To study the efficient energy management for a grid tied residential microgrid | R | Multi objective |
| [15] | Server provisioning methods | To study the integration of server provisioning & power procurement | C | Multi objective |
| [16] | Demand energy resource (DER) based on multi-frequency agent coordination | To increase stability & reduce stress of electric grid | C, I | Multi objective |
| [17] | Co-ordinated optimisation | To evaluate the effect of social interaction on a distributed DSM | R | Single objective |
| [18] | DSM & Multi-pronged approach | To study the use of DSM for power distribution | C,I | Multi objective |
| [19] | Demand response (DR) programmes | TO study the effects of Demand response (DR) in electricity markets | R, C | Multi objective |
| [20] | DR strategies & Advanced metering infrastructure(AMI) | To study the impact of time of use (TOU) rates on distributed load shapes in a smart grid with PHEV penetration | R | Single objective |
| [21] | Automated DR based control approaches | To study automated DR strategies & commissioning commercial building control | C | Multi objective |
| [22] | Co–ordinated scheduling | To optimize smart home energy services | R | Single objective |
| [23] | Binary PSO | To schedule Demand side resources | C, I | Multi objective |
| [24] | Direct load control | To control Air conditioning loads | C, I | Single |

| | | | | |
|---|---|---|---|---|
| | | | | Objective |
| [25] | Interoperable Automated DR technique | To design & implement of an open, interoperable Automated DR infrastructure | R,C | Multi objective |
| [26] | Sequential simulation | To study the improvement of available transfer capability by DSM | C | Single objective |
| [27] | Load management technologies | To study concept of DSM for electric utilities | R,I | Single objective |
| [28] | Phase change material (PCM) methodology | To study efficient thermal energy storage using PCM | R | Multi objective |
| [29] | Game theory based & proximal algorithm | To study distributed DSM | R,I | Multi objective |
| [30] | Distributed &co-operative power control algorithm | To study DSM with Zegbee sensors | R,C | Single objective |
| [31] | Novel appliance commitment algorithm | To schedule household load | R | Multi objective |
| [32] | Analytical & Iterative method | To develop an efficient model to analyze impacts of DSM | C,I | Single objective |
| [33] | Versatile model &Decentralized algorithm | To formulate optimal DR problem | C,I | Multi objective |
| [34] | Active house energy management system | To schedule residential electric load for Green house e gas (GHG) reduction | R | Multi objective |
| [35] | DR modelling | To study the impact of DR on Distributed system reliability | R,C | Single objective |
| [36] | Game theoretic methods | To study the implementation of game theoretic methods | C | Multi objective |
| [37] | Building automation system (BAS) technique | To study the regulation needs of the grid | C | Single objective |
| [38] | Stochastic pricing Analysis | To analyze the stochastic pricing capacity controlled DSM | R | Single objective |
| [39] | Stochastic & convex optimisation | To study the DR of data centers in deregulated energy market | C,I | Multi objective |
| [40] | DR based smart grid techniques | To study DR as a market resource | R,C | Multi objective |
| [41] | Mathematical modelling & approaches | To study the survey on DR in smart grids | R,C | Multi objective |
| [42] | Adaptive time series techniques | To forecast loads & prices in competitive power markets | R,C,I | Multi objective |
| [43] | Secondary optimisation | To intensify energy efficiency in secondary distributed system | R,C | Multi objective |

The optimization functions are formulated as single objective and multi objective functions. From the literature it can also be observed that various techniques and methodologies of demand side management (DSM) are implemented through demand response (DR) in order to enhance the energy efficiency. These DSM based methodologies not only help to improve the energy efficiency but it also recommends the guidelines how to reduce the energy bills, and along with this it also provides incentives to end users to motivate them for the energy consumption. DSM lowers the level of carbon and green-house gases emissions which are responsible for pollution. Hence apart from energy consumption, these DSM techniques promote environmental friendliness operation of electrical systems.

## 1.3 Research gap

Form the literature it can be observed that the DSM problem has the major scope of research as follows,

### 1.3.1 Operating cost minimization

The operating cost of the power system mainly depends upon the peak load demand, power loss and the number of customer supplied at particular duration. Therefore, the scope of cost minimization is a never ending process because the operating constraints always change with state of economy and the time passage in smart grid or micro-grid scenario

### 1.3.2 Demand response

For a particular load area the energy requirements is not uniform for all the time. This has varied the peak and minimum demand for that area. The response of the demand in a particular area needs to be study for identification of potential energy savings. Therefore, the involvement of the customer in energy management is possible through demand response.

### 1.3.3 Load shifting

As discussed in section 1.3.2, that the load demand keep on varying in a particular area and it has the scope of shifting of load from one region to another. This will allow the power utilities to minimise the generation and to meet the maximum number of consumers simultaneously.

### 1.3.4 Energy efficiency

It is defined as the goal to reduce the amount of energy consumption without compromising the customer's comfort level.

### 1.3.5 Integration of DER

The integration of local power generation is the effective means to improve the system performances and hence to enhance the energy efficiency.
The implementation of DSM schemes requires the recommendations given by the BEE guidelines and or as per the survey conducted by the certified energy manager and auditors.

The economy of any nation has energy consumption as one of the parameters for its growth. Thus, DSM has now been the important area of research since DSM reduces the chances of overloading and interruptions of power supply.

## 1.4 Objectives

From the related literature it can be observed that the energy efficiency is the cost effective mean of energy saving. Also saving of single unit of energy is always viewed as the energy source. In practice, a commercial building is believed to have several electrical components which operate together. The energy power consumption of these equipment is different and they include lighting system, air circulator, air conditioning and heating system. The requirement of these equipment depends upon the number of persons involved in a specific area, surrounding environmental conditions and the availability of the supply. Therefore, considering these aspects, the main objectives of this thesis are summarised as under,

1. **To determine the energy efficiency of Light ventilation & air conditioning(LVAC) with respect to the task areas and non-task areas in a commercial and residential building i.e.**
    - Illuminance per unit area
    - Air circulation per unit area
    - Cooling per unit area
2. **To recommend consumption levels suitable for various activities.**
3. **To determine the overall energy efficiency of LVAC systems using measurements and methods suitable for field conditions.**

However, in this thesis work the above objectives are subject to the following constraints,

- Social behaviour
- Environmental conditions
- Energy consumed after DSM < Energy consumed before DSM

## 1.5 Conclusion

This chapter presented an extensive review of the DSM techniques for the improvement of energy efficiency in distribution systems (EEDS). From the literature it has been observed that the DSM problem is formulated by the researchers in different ways. In the problem formulation researcher have focused on the minimization of operating cost and hence to reduce the peak demand and power losses simultaneously. The reduction in peak demand ultimately improve the sustainability of smart grids by supply more number of customer from the existing network structure, i.e. without expansion. In the related literature, demand response and home energy management are considered as the major component for effective implementation of the DSM schemes. Further, DSM provides additional incentives to the end users and promotes environment friendliness because it reduces the carbon level and green-house gases emissions which are highly responsible for pollution. DSM techniques have various benchmarks to make the future smart grid more efficient which tries to maintain the level of customer comfort by keeping balance between supply and consumers.

# CHAPTER 2
# TERMINOLOGIES AND MATHEMATICAL FORMULATIONS

## 2.1. Introduction

The efficiency of a light source, fan and air conditioner varies with the change in operating conditions, surrounding environment and their operating lifespan. Practically, it is difficult to establish the luminous efficacy value of lamps at site conditions.

A second aspect of efficiency of utilisation is to take into account, the light available at task and non-task areas. Usually for commercial areas, the recommended illuminance at the non-task areas is at least one-third of the average task illuminance, while keeping a minimum illuminance required at the horizontal plane to be 20 lux. From illuminance measurements the ratio of illuminance at non task areas and task areas can be estimated to understand whether the non-task illuminance level is more than required or not. This code defines and describes the methods for evaluating energy efficiency of indoor lighting systems in the following end user categories.

a. Industrial buildings
b. Commercial buildings
   i. Hospitals
   ii. Hotels
   iii. Academic institutions
c. Residential buildings

## 2.2. Basic terminologiesandmathematical formulations

The basic terminologies developed for lighting system, fan and air-conditioner which are used in mathematical formulation of energy efficiency in a commercial and residential building in this work are defined as under.

### 2.2.1 Lighting system & its components

All the light emitted by the lamp does not reach the work area. Some light is absorbed by the luminaire, walls, floors & roof etc. The illuminance measured, in lumens/$m^2$ i.e. lux, indicates how much light i.e. lumens is available per square metre of the measurement plane. Target luminous efficacy (lm/watts) of the light source is the ratio of lumens that can be made available at the work plane under best luminous efficacy of source, room reflectance, mounting height and the power consumption of the lamp circuit. Ideally, we would expect the target luminous efficacy to be available on the work plane. However, over a period of time the light output from the lamp gets reduced, room surfaces becomes dull, luminaries becomes dirty and hence the light available on the work plane deviates from the target value. The ratio of the actual luminous efficacy on the work plane and the target luminous efficacy at the work plane is the Installed Load Efficacy Ratio (ILER).

### A. Circuit watts

Total power consumption of lamps plus ballasts in the lighting feeder/circuit under consideration

### B. Colour rendering index

It is the parameter through which the light source capability is checked to identify the colour of all the objects more accurately as compared to the other sources of light.

### C. Installed load efficacy

This is defined as the ratio of average luminous flux on the surface per circuit watt with general lighting of an interior expressed in **lux/W/m².**

$$\text{Installed Load Efficacy, ILE} = \frac{\text{Averageluminousfluxonthesurface}}{\text{Circuitwatts}} \text{ ln/watts} \quad (1)$$

### D. Installed load efficacy ratio

This is the ratio of installed Load efficacy and target load efficacy.

$$\text{Installed load efficacy ratio, ILER} = \frac{\text{Installed load efficacy}}{\text{Target load efficacy}} \quad (2)$$

**Table 2.1:Indicators of performance based on ILER**

| ILER | Assessment |
|---|---|
| 0.75 or above | Satisfactory to good |
| 0.51 to 0.74 | Review suggested |
| **0.5 or less** | **Urgent action required** |

The reasons for ILER to be lower than desired can be due to any of the following.

- Inefficient lamps and/or ballasts
- Mounting height of lamps too high

- Reflectors of poor luminare efficiency
- Maintenance of reflectors not proper due to dirt/dust accumulation
- Poor Maintenance of wall, floor and roof reflectance levels
- Reduction in light output of lamps over time due to lumen depreciation

**E. Lumen**

Unit of luminous flux; the flux emitted within a unit solid angle by a point source witha uniform luminous intensity of one candela. One lux is one lumen per square meter.

**F. Luminaire**

A luminaire is a complete lighting unit, consisting of a lamp or lamps togetherwith the parts designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

**G. Lux**

This is the metric unit of measure for illuminance of a surface. Average maintained illuminance is the average of lux levels measured at various points in a defined area. One lux is equal to one lumen per square meter.

**H. Mounting height**

The height of the fixture or lamp above the working plane.

**I. Rated luminous efficacy**

The ratio of rated lumen output of the lamp and the rated power consumption expressed in lumens per watt.

**J. Room index**

This is a ratio, which relates the plan dimensions of the whole room to theheight between the working plane and the plane of the fittings. It is very important parameter as it gives us information about number of points in a room where light intensity is to be measured. The formula is given by

$$\text{Room index, RI} = \frac{L*W}{H_m+(L*W)} \quad (3)$$

Where,

L = Length

W = Width

$H_m$= Height of the luminaires above the plane of measurement.

**Table 2.2: Number of points for measuring illuminance [BEE]**

| Range of RI | For ± 5% accuracy | For ± 10% accuracy |
|---|---|---|
| RI<1 | 8 | 4 |
| 1<RI<2 | 18 | 9 |
| 2<RI<3 | 32 | 16 |
| RI>3 | 50 | 25 |

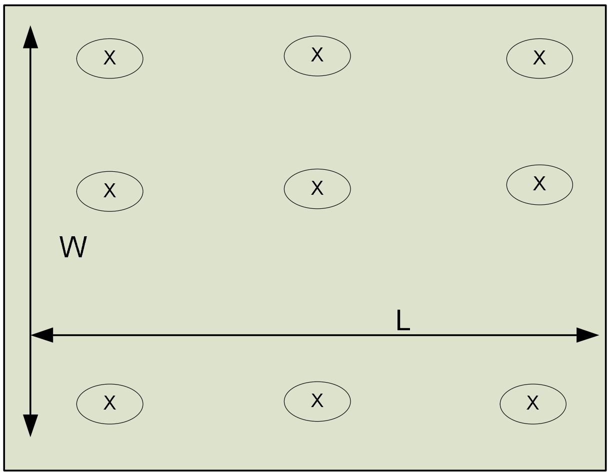


**Fig. 2.1: Room index calculations for a sample room**

If a room has following dimensions i.e. $l$=5m, w=5m and h=2.6m, where $l$,w and h are length, width of a room and h is mounting height of lamp respectively. RI comes out to be 0.96, this means 8 measurement points should be there. But in figure above, the selected points are 9.To cover the area represented of the working plane, the measurement grid needs to be positioned. For the determination of illuminance level, the number of measurement points is recommended to be large in number. This helps in the calculation purpose of illuminance in wide variations. So that the resultant average of the illuminance can be accurate.

## K. Target load efficacy

The value of Installed load efficacy considered being achievable under best efficiency, expressed in lux/W/m².

**L. Utilisation factor**

This is the proportion of the luminous flux emitted by the lamps, which reaches the working plane. It is a measure of the effectiveness of the lighting.

**M. Task area**

It is defined as the area where light is necessary & it is working area where most of the work is being done.

**N. Non-task area**

It is defined as the area where light is not required & it is non- working area.

**O. Average illuminance**

It is defined as the ratio of average sum of all the illuminance which is measured at all points of room by N which is no. of points to be measured , multiplied with the correction factor. Mathematically,

$$\mathrm{E_{av}} = \frac{\mathrm{E1+E2+..+EN}}{\mathrm{N}} * \text{Correction Factor} \quad (4)$$

**P. Total available lumens**

This is defined as the product of average illuminance & the area of the room.

$$\text{Mathematically,} \emptyset_m = E_{av} * L * W \quad (5)$$

Where $E_{av}$is the average illuminance, L & W are the length and width of the room respectively.

**Q. Illuminance measurement points ($IMP_{task\ area}$)**

The no. of $IMP_{task\ area}$should be installed are calculated by the following formula;

$$IMP_{task\ area} = \frac{\mathrm{A_{task}}}{\mathrm{A_{task}+A_{non\ task}}} * \text{Total no. of illuminance measurement points} \quad (6)$$

**R. Illuminance measurement points (IMP) non task area**

The number of IMP non task area which should be installed are calculated by the formula,

$$IMP_{non-task\ area} = \frac{\mathrm{A_{non\ task}}}{(\mathrm{A_{task}+A_{non\ task}})} * \text{Total no. of illuminance measuring points} \quad (7)$$

**S. Diversity ratio**

It is defined as ratio of average illuminance of task area to the average illuminance of non-task area. Mathematically,

$$\text{Diversity Ratio (DR)} = \frac{E_{\text{avg task area}}}{E_{\text{avg non task area}}} \tag{8}$$

It is the indicator of task lighting effectiveness which involves measurement of illuminance on task and non-task area.

DR is very important parameter for calculation of energy efficiency of lighting system. For the general lighting purpose, the DR should be taken as 3:1. However, the DR range can be exceeded to 10:1 for higher illuminance order of 700-1000-2000 lux. The need for changing lighting scheme is required when the DR is less than 3:1. It can also be observed that the illuminance at non task area should have at least 20 lux. DR is expected to be 3:1 for effective lighting for usual commercial area.

**T. Room cavity ratio**

It is given by the following formula,

$$\text{Room cavity ratio(RCR)} = 5H_m \frac{(L+W)}{LW}$$

Where L, W and $H_m$ are the length, width and height of room respectively.

### 2.2.2 For Fans

**A. Average velocity**

The average speed of an object is defined as the distance travelled divided by the time elapsed. As velocity is vector quantity, so average velocity can be defined as displacement by the time. In other words, it is defined as the rate of change at which an object changes its position from one place to another.

**B. RPM**

It is defined as the speed of rotation of a machine expressed in revolutions per minute.

**C. Fan laws**

The fans operate under a predictable set of laws concerning speed, power and pressure. The change in speed of any fan (RPM) will predictably change the pressure rise and power necessary to operate it at new RPM.

**D. Cubic feet per minute**

It is defined as the ratio of volume of the room by the air change flow per hour. CFM is very important parameter as it decides the number of fans required to be installed in a room. The air change flow per hour depends upon the type of room e.g. living room, kitchen, wash room etc.

$$\text{CFM}=\frac{\text{Volume of the room( in cubic feet)}}{\text{Air change flow per hour}} \tag{9}$$

**E. Number of fans**

The number of fans required to be installed in a room is calculated by the formula;

$$\text{Number of fans}=\frac{\text{CFM required in unit area}}{\text{Wattage}*\text{energy efficiency of a fan}} \tag{10}$$

Energy efficiency of fan is nearly equal to 60-90%.

**F. Energy efficiency of fan**

The energy efficiency of a fan is defined as the ratio of CFM by the wattage of the fan.

$$\text{EE of Fan} =\frac{\text{CFM}}{\text{Wattage}} \tag{11}$$

It varies between 60-90 at full speed and energy efficiency of the fan is in this work is taken as 70%.

### 2.2.3 For Air conditioners

**A. Tons of refrigeration**

1 ton of refrigeration(TR) = 3024 kcal/hr heat rejected

**B. Coefficient of performance**

The coefficient of performance (COP) is a measure of the amount of power input to a system compared to the amount of power output by that system. The COP is therefore a measurement of efficiency; the higher the number, the more efficient the system is. The COP is dimensionless because the input power and output power are measured in Watt.

The COP is also an instantaneous measurement in that the units are power which can be measured at one point in time.

**C. Energy efficiency ratio**

The energy efficiency ratio (EER) is the ratio of output cooling energy (in BTU) to electrical input energy (in Watt-hour).

$$\text{EER} = \frac{\text{output cooling energy (in BTU)}}{\text{input electrical energy (in Watt−hou )}} \quad (12)$$

**D. Seasonal energy efficiency ratio**

Seasonal energy efficiency ratio (SEER ) is the ratio of output cooling energy (in BTU) to electrical input energy (in Watt-hour).

$$\text{SEER} = \frac{\text{output cooling energy (in BTU)}}{\text{input electrical energy (in Watt−hour)}} \quad (13)$$

**E. Kilo-watt per ton**

The efficiencies of large industrial air conditioner systems, especially chillers, are given in kW/ton to specify the amount of electrical power that is required for a certain power of cooling.

$$\frac{\text{Power output in Watts}}{\text{Power input in Watts}} = \frac{3.517}{\text{KW/ton}} \quad (14)$$

For the calculation of number of ACs required to be installed in a room two methods are used.

- Area method
- Volume method

**A. Area method**

This method has two criteria which gives information of calculation of number of ACs recommended to be installed in a room.

Criteria -1:

$$\text{Tonnage Required/unit area} = \frac{\text{Area}*25}{12000}\ \text{tonnes} \quad (15)$$

Criteria -2:

$$\text{Tonnage Required/unit area} = \frac{\text{Area(square root of square feet)}}{10}\ \text{tonnes} \quad (16)$$

**B. Volume method**

This method has one criteria gives information of calculation of number of ACs recommended to be installed in a room.

Criteria-3:

$$\text{Tonnage Required/unit volume} = \frac{\text{Volume (Cubic feet)}}{1000}\,\text{tonnes} \quad (17)$$

## 2.3 Conclusion

This chapter describes the various terminologies and the mathematical formulations of lighting system, fans and ACs which are used in the energy auditing strategies. The various parameters like room index, load efficacy, illuminance intensity, room cavity ratio, diversity ratio and number of luminaries etc. The terminologies and mathematical formulations described in this chapter help in the procedure of energy auditing to enhance energy efficiency by reducing monthly electricity costs.

# CHAPTER 3
# DATA COLLECTION AND ANALYSIS

## 3.1 Introduction

This chapter describes the data collection and analysis of D-Block of Thapar Institute of Engineering and Technology, Patiala. The data which is collected includes hourly data of energy of all fans and tubes, energy of all air conditioners ACs which are installed in all rooms of D-Block. Along with this, the temperature, humidity and luminous intensity of surrounding atmosphere has also been taken. This data has been collected on all week days i.e. Monday to Friday on hourly basis from 9 AM to 5 PM. The data is taken for duration of 8 hours i.e. from 9 AM to 5 PM because these are the working hours of TIET. This hourly data has been taken for week days only because energy is being consumed much on week days. Saturday & Sunday are the off days, so energy does not get consumed much and it has been constant on all Saturdays and Sundays as there is no or very less load on Saturdays and Sundays. Temperature, humidity, luminous intensity and the number of people are the important parameters on which energy efficiency depends. So energy efficiency can be improved by analysing the parameters it depends upon. The collected data also includes measurements of luminous intensity in different parts of all rooms of D–Block. This collected data of luminous intensity has been taken on the seasonal months of August 2018, January and April 2019. The data has been taken in only these three months because these three months are the seasonal months where the temperature changes drastically.

The data collection also includes checking number of fans, lights and ACs in all rooms of D-Block. Lights have been categorized in three categories: Single tube light, CFL(Double) and Double Tube light. The tonnage of ACs of each room have also been checked. The data collected also includes number of substations in TIET. This includes number of transformers and diesel generators (DG) sets along with their ratings of each substation. This also includes name of the blocks which are to be fed by these substations . These blocks includes all the academic area and the entire TIET campus along with the hostels, cafeteria, swimming pool etc.. These all are the collected data from D-Block of TIET. These are the actual data collected and various strategic auditing techniques have been employed to improve energy efficiency and discussed in the next chapter.

## 3.2 Substation and energy data

Table 3.1 shows the data sheet of various components at different substation at TIET campus. The sanctioned load of TIET is 4.140MW.

**Table 3.1: Substation data**

| SS | DG Sets | | Transformer | | Load | Remarks |
|---|---|---|---|---|---|---|
| | Qty | Rating (kVA) | Qty | Rating (kVA) | | |
| 1 | 2 | 400 | 1 | 2000 | 1600-1800A(Maximum) | Total academic area including: A, B,C,D, link blocks, G, H, Auditorium, workshops, learning block,Tan building. |
| | 1 | 320 | | | | |
| 2 | 1 | 500 | 1 | 500 | 350-400A | Hostel A,B,C,D(Baba Maddi),PG(ac only) |
| | 1 | 400 | 1 | 1000 | 600A | Hostel J,H(ac only),C, water pump supply |
| 3 | | | 1 | 500 | T/F 1: 550-600A(maximum) | Hostel I(Normal supply& ac), G, E, Dispensary, core building, COS building |
| | | | 1 | 250 | T/F 2: 80-100A(maximum) | |
| | 1 | 380 | | | DG load:350-415A(maximum) | |
| 4 | 1 | 320 | 1 | 1250 | T/F load:700-750A(maximum) | Hostel L,K,STP plant when needed(it is under abnormal condition that supply is fed from substation no. 4 ,otherwise STP is fed by substation no. 3 in normal condition). |
| 5 | | | | | DG load:280-300A | Hostel M only |
| | | | 2 | 2000 | T/F 1:850A | |
| | | | | | T/F 2: 900A | |
| | 2 | 750 | | | DG 1:700A | |
| | | | | | DG 2: 650A | |
| 6 | | | 1 | 2000 | T/F loads: | Hostel N, chillar plants, chillar pump, AC academic block, Only one DG set is in working condition.2 transformers are in working condition. |
| | | | | | phases: | |
| | | | | | 1=1,011KA | |
| | | | | | 2=979KA | |
| | | | | | 3=972KA | |
| | | | | | DG load: | |
| | 3 | 750 | | | 750A(maximum) | |
| 7 | | | 1 | 500 | T/Fload:416A | All R&D department, Sai lab, library, Director's house, all residence behind library |
| | 1 | 160 | | | DG Load:250-300A | |

Through substation data, the information that we obtained is the number of DG sets, transformers, total load fed by particular transformer and generator along with their ratings. This data also tells the load drawn by the DG sets and transformers for all the substations along with their maximum load capacity. The data also gives information about number & names of the blocks to be fed by these substations. There are total 7 substations in TIET i.e. Substation number 1, 2, 3, 4, 5, 6 and 7. Among all, substation number 1 is the most bulky substation as it feed power to the major portions of TIET campus.

### 3.2.1 Energy data for month of August'18

Table 3.2 gives the information of average energy consumption for all the Mondays, Tuesdays, Wednesdays, Thursdays and Fridays for the month of August'18. From the data, it can be observed that there is significant variation in the energy consumption from 9AM to 5PM and it is different in different day of the week.

**Table 3.2: Average energy consumption for the month of August'18**

| Days of Week | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| Monday | 25 | 20 | 30.25 | 22 | 21.25 | 27.25 | 24.75 | 20.5 |
| Tuesday | 43.2 | 39.8 | 46.2 | 45.4 | 31.8 | 37.8 | 40.2 | 28 |
| Wednesday | 32.6 | 31 | 27.8 | 33 | 25 | 55.8 | 32.2 | 60.2 |
| Thursday | 32.2 | 32.4 | 43.2 | 36.6 | 31.4 | 34.8 | 38.4 | 41.2 |
| Friday | 43.2 | 40.4 | 43.6 | 20.8 | 43.6 | 30.2 | 37.8 | 34.8 |

### 3.2.2 Data analysis for month of August'18

Table 3.3 shows the variation in temperature, humidity, luminous intensity and energy consumption for all components including fans and tube lights and ACs in D- Block in the month of August'18 for one day. This data is taken on hourly basis i.e. from 9AM to 5PM. This data gives the information of load variation of the complete day which further helps in load shifting at the time of peak loads. However, the variation in these parameters for whole month is given in Appendix-A.

**Table 3.3: Monthly energy consumption for the month of August'18**

| Variation in various parameter from 9AM to 5PM on 14-08-2018 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter/Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
| Temp($^o$C) | 28 | 29 | 29 | 30 | 30 | 31 | 31 | 30 |
| Humidity(%) | 90 | 86 | 85 | 83 | 81 | 79 | 77 | 78 |
| EC_FnT (kWh) | 40 | 40 | 50 | 30 | 0 | 10 | 30 | 0 |
| E_AC(kWh) | 7 | 0 | 0 | 0 | 6 | 4 | 4 | 4 |
| EC_Total (kWh) | 47 | 40 | 50 | 30 | 6 | 14 | 34 | 4 |
| LI(Lux) | 19758 | 21736 | 23018 | 25872 | 26142 | 29879 | 27628 | 28162 |

### 3.2.3 Energy data for month of January'19

In this section, the monthly data of readings which are taken on hourly basis will be discussed. Table 3.4 gives the information of average energy consumption for all the Mondays, Tuesdays, Wednesdays, Thursdays, Fridays for the month of January'19. From table 8 it can be observed that the power consumption varies significantly from Monday to Friday throughout a day.

**Table 3.4: Average energy consumption for the month of January'19**

| Days | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| Monday | 12 | 12 | 12 | 8 | 10 | 10 | 10 | 8 |
| Tuesday | 10 | 10 | 10 | 12 | 8 | 10 | 8 | 6 |
| Wednesday | 12 | 8 | 10 | 8 | 10 | 8 | 10 | 10 |
| Thursday | 10 | 10 | 10 | 10 | 10 | 8 | 10 | 10 |
| Friday | 10 | 12.5 | 12.5 | 10 | 10 | 10 | 7.5 | 7.5 |

### 3.2.4 Data analysis for month of January'19

Table 3.5 shows the variation in temperature, humidity, luminous intensity and energy consumption for all components including fans and tube lights and ACs in D- Block in the month of January'19 for one day. This data is taken on hourly basis i.e. from 9AM to 5PM. This data gives the information of load variation of the complete day which further helps in load shifting at the time of peak loads. However, the variation in these parameters for whole month is given in Appendix-B.

**Table 3.5: Monthly energy consumption for the month of January'19**

| Variation in various parameter from 9AM to 5PM on 07-01-2019 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter/Time (AM/PM)** | **9:00-10:00** | **10:00-11:00** | **11:00-12:00** | **12:00-1:00** | **1:00-2:00** | **2:00-3:00** | **3:00-4:00** | **4:00-5:00** |
| Temp($^{o}$C) | 7 | 10 | 12 | 14 | 17 | 19 | 18 | 19 |
| Humidity(%) | 95 | 93 | 92 | 91 | 91 | 88 | 89 | 87 |
| EC_FnT (kWh) | 10 | 10 | 10 | 0 | 10 | 10 | 10 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 0 | 10 | 10 | 10 | 0 |
| LI(Lux) | 985 | 3610 | 4489 | 7848 | 56145 | 64592 | 58987 | 60472 |

### 3.2.5 Energy data for month of April'19

In this section, the monthly data of readings which are taken on hourly basis will be discussed. Table 3.6 represents the average energy consumption for all the mondays, tuesdays, wednesdays, thursdays and fridays for the month of April'19. The monthly energy readings of all saturdays & sundays are not taken because these are the off days, so energy does not get consumed much and it has been constant on all saturdays and sundays as there is no or very less load on weekends whereas in week days the variation in energy consumption has not been significant and it varies drastically in Thapar institute of engineering and technology, Patiala.

**Table 3.6: Average energy consumption for the month ofApril'19**

| Days of week | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| Monday | 28.6 | 27 | 30.8 | 24.6 | 31.4 | 30.4 | 27.4 | 23.8 |
| Tuesday | 29 | 31.4 | 31.4 | 27 | 28.2 | 33.6 | 24.4 | 25.8 |
| Wednesday | 31 | 30 | 36 | 27 | 38 | 48 | 28 | 28 |
| Thursday | 22.5 | 27 | 32.75 | 27.5 | 31 | 37.75 | 34 | 33 |
| Friday | 28.75 | 29.5 | 25.75 | 30.5 | 29.5 | 31.75 | 30.5 | 28 |

### 3.2.6 Data analysis for month of April'19

Table 3.7 shows the variation in temperature, humidity, luminous intensity and energy consumption for all components including fans and tube lights and ACs in D- Block in the month of April'19 for one day. This data is taken on hourly basis i.e. from 9AM to 5PM. This data gives the information of load variation of the complete day which further helps in load shifting at the time of peak loads. However, the variation in these parameters for whole month is given in Appendix- C.

**Table 3.7: Monthly energy consumption for the month of April'19**

| Variation in various parameter from 9AM to 5PM on 08-04-2019 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter/Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
| Temp($^{o}$C) | 25 | 27 | 28 | 30 | 33 | 36 | 36 | 35 |
| Humidity(%) | 69 | 60 | 50 | 42 | 41 | 40 | 37 | 38 |
| EC_FnT (kWh) | 1010 | 1010 | 1020 | 1020 | 1020 | | 10 | 10 |
| E_AC(kWh) | 4 | 3 | 4 | 4 | 3 | 5 | 5 | 5 |
| EC_Total (kWh) | 14 | 13 | 24 | 24 | 23 | 15 | 15 | 15 |
| LI(Lux) | 29984 | 36569 | 38742 | 43628 | 56741 | 58262 | 67675 | 63108 |

## 3.3 Data analysis of fans

**Table 3.8: Fan data analysis of D-block**

| Room No | Room size in feet | | | Fan | Fan load |
|---|---|---|---|---|---|
| | Length | Breadth | Height | | |
| D106 | 18.5 | 8.67 | 8.42 | 2 | 120 |
| D104 | 38 | 30 | 8.83 | 7 | 420 |
| D107 | 18.5 | 8.67 | 8.42 | 2 | 120 |
| D108 | 18.5 | 8.67 | 8.42 | 2 | 120 |
| D109 | 18.5 | 8.67 | 8.42 | 2 | 120 |
| D110 | 18.5 | 8.67 | 8.42 | 2 | 120 |
| D101(CAM LAB) | 29.916 | 24.42 | 9.08 | 6 | 360 |
| D102(CAD LAB -2) | 29.92 | 24.42 | 9.08 | 6 | 360 |
| D116 | 41.25 | 50.5 | 11.83 | 16 | 960 |
| D115 | 41.25 | 50.5 | 11.83 | 12 | 720 |
| Research Lab | 35 | 9.42 | 9 | 4 | 240 |
| D201 | 35.75 | 29.83 | 9.42 | 11 | 660 |
| D202 | 35.75 | 29.83 | 9.42 | 11 | 660 |
| D203 | 29.66 | 18.33 | 9.42 | 5 | 300 |

| | | | | | |
|---|---|---|---|---|---|
| D204 | 29.66 | 18.33 | 9.42 | 5 | 300 |
| Cabin near str. lab | 12.75 | 12.42 | 12.42 | 1 | 60 |
| Structure Lab | 157 | 30.75 | 16.08 | 36 | 2160 |
| D120 | 13 | 10 | 13.83 | 1 | 60 |
| Dr. Tapas cabin | 30.75 | 13 | 13.83 | 2 | 120 |
| D112(Lab) | 31.75 | 28.5 | 8.92 | 11 | 660 |
| Transportation Lab | 49.42 | 29 | 12.92 | 15 | 900 |
| D117 | 30.42 | 12.25 | 14.25 | 2 | 120 |
| D114 | 18.58 | 8.58 | 14.42 | 2 | 120 |
| D113 | 18.58 | 8.58 | 14.42 | 2 | 120 |
| D111(MED Office) | 18.75 | 19.83 | 9.17 | 2 | 120 |
| D123 | 13 | 10 | 13.83 | 1 | 60 |
| Dr.T.P cabin | 19.33 | 8.67 | 8.42 | 2 | 120 |
| D103 | 13 | 10 | 13.83 | 1 | 60 |
| D118 | 30.42 | 22.67 | 9.33 | 4 | 240 |
| Room near stairs | 12.75 | 12.42 | 12.42 | 1 | 60 |
| D119 | 13 | 10 | 13.83 | 1 | 60 |
| D121 | 12.83 | 12.25 | 9.42 | 1 | 60 |

Table 3.8 gives complete information about all the rooms in the D Block. The information contains the room data such as size of all the rooms of D block i.e. area of all rooms, number of fans installed in each room and fan load in each room. This data helps to check the various important parameters of fans on which the energy efficiency depends. By using this data, the energy efficiency of fans can be calculated.

## 3.4 Data analysis of Air Conditioners

**Table 3.9 : AC data analysis of D-block**

| Room No. | AC | | AC load |
|---|---|---|---|
| | Qty | Capacity in Tonnes | |
| D106 | 1 | 1.5 | 3420 |
| | 1 | 1 | 2280 |
| D104 | 2 | 2 | 4560 |
| | 1 | 1.5 | 3420 |
| D101(CAM LAB) | 4 | 2 | 4560 |
| D102(CAD LAB -2) | 4 | 2 | 4560 |
| Research Lab | 2 | 1.5 | 3420 |
| D201 | 4 | 2 | 4560 |
| D202 | 4 | 2 | 4560 |
| D203 | 2 | 1.5 | 3420 |
| D204 | 2 | 1.5 | 3420 |
| Cabin near Str. Lab | 1 | 1.5 | 3420 |
| D112(Lab) | 4 | 2 | 4560 |
| Dr.T.P cabin | 1 | 1 | 2280 |
| D118 | 4 | 1.5 | 3420 |
| D119 | 1 | 1 | 2280 |

The data given above in table 3.9 gives the complete information about number of air conditioners installed in each room and the tonnage of each unit. Along with this, the total AC load is also given.

### 3.5 Data analysis of lights

**Table 3.10 :Light data analysis of D- block**

| Room No. | Length (ft) | Breadth (ft) | Height (ft) | Tubelight (single) | CFL (double) | Tubelight (double) | Light Load (W) |
|---|---|---|---|---|---|---|---|
| D106 | 18.50 | 8.67 | 8.42 | 2 | 3 | 3 | 490 |
| D104 | 38 | 30 | 8.83 | -- | -- | 13 | 1300 |
| D107 | 18.5 | 8.67 | 8.42 | 2 | 1 | -- | 130 |
| D108 | 18.5 | 8.67 | 8.42 | 2 | 1 | -- | 130 |
| D109 | 18.5 | 8.67 | 8.42 | 3 | -- | -- | 150 |
| D110 | 18.5 | 8.67 | 8.42 | 3 | -- | -- | 150 |
| D101 | 29.92 | 24.42 | 9.08 | -- | -- | 9 | 900 |
| D102 | 29.92 | 24.42 | 9.08 | -- | -- | 8 | 800 |
| D116 | 41.25 | 50.5 | 11.83 | -- | -- | 26 | 2600 |
| D115 | 41.25 | 50.5 | 11.83 | -- | -- | 26 | 2600 |
| Research Lab | 35 | 9.42 | 9 | -- | -- | 4 | 400 |
| D201 | 35.75 | 29.83 | 9.42 | -- | 14 | 6 | 1020 |
| D202 | 35.75 | 29.83 | 9.42 | -- | 14 | 6 | 1020 |
| D203 | 29.66 | 18.33 | 9.42 | -- | 11 | -- | 330 |
| D204 | 29.66 | 18.33 | 9.42 | -- | 11 | -- | 330 |
| Cabin near structure lab | 12.75 | 12.42 | 12.42 | -- | -- | 2 | 200 |
| Structure Lab | 157 | 30.75 | 16.08 | 4 | 14 | 15 | 2120 |
| D120 | 13 | 10 | 13.83 | 2 | -- | -- | 100 |
| Dr. Tapas cabin | 30.75 | 13 | 13.83 | 3 | -- | -- | 150 |
| D112 | 31.75 | 28.5 | 8.92 | -- | -- | 8 | 800 |
| Transportation Lab | 49.42 | 29 | 12.92 | -- | 20 | -- | 600 |
| D117 | 30.42 | 12.25 | 14.25 | 2 | -- | -- | 100 |
| D114 | 18.58 | 8.58 | 14.42 | -- | 2 | -- | 60 |
| D113 | 18.58 | 8.58 | 14.42 | -- | 2 | -- | 60 |
| D111(MED Office) | 18.75 | 19.83 | 9.17 | -- | 4 | -- | 120 |
| D123 | 13 | 10 | 13.83 | 2 | -- | -- | 100 |
| Dr. TP cabin | 19.33 | 8.67 | 8.42 | 2 | 4 | -- | 220 |
| D103 | 13 | 10 | 13.83 | 2 | -- | -- | 100 |
| D118 | 30.42 | 22.67 | 9.33 | -- | 6 | 8 | 980 |
| Room near stairs | 12.75 | 12.42 | 12.42 | -- | -- | 4 | 400 |
| D119 | 13 | 10 | 13.83 | -- | -- | 4 | 400 |
| D121 | 12.83 | 12.25 | 9.42 | -- | -- | 4 | 400 |
| Corridor-1 | 418.08 | 11.67 | 8.83 | 6 | -- | 2 | 500 |
| Corridor-2 | 62.42 | 19.92 | 12.58 | 1 | -- | 1 | 150 |

Table 3.10 gives complete information about all the rooms in the D Block. The information contains the room data such as size of all the rooms of D block i.e. area of all rooms, number of fans installed in each room and fan load in each room. This data helps to check the various important parameters of light system on which the energy efficiency depends. By using this data, the energy efficiency of lighting system can be calculated. Here, the number of components in each room found to be different even for the same size.

### 3.6 Actual layout of sample room in D-Block

These figures describe the layout of D- Block of TIET, Patiala. The complete layout of D-Block has been done. In these figures, the layout of one seminar room, one lab, one class room and one faculty cabin has been shown. These figures tells the data that how many fans, tube lights and ACs are installed in that particular room. These figures gives the clear picture of number of electrical appliances installed in a particular room.

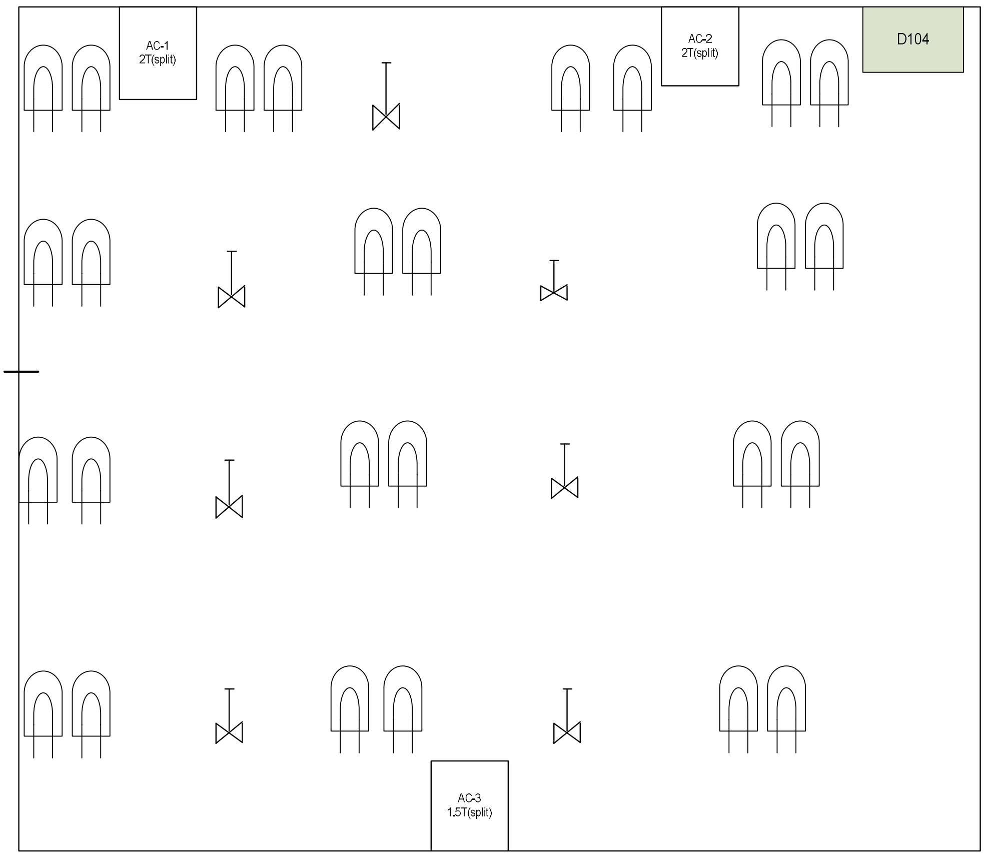


**Figure 3.1 : Layout of seminar Room**

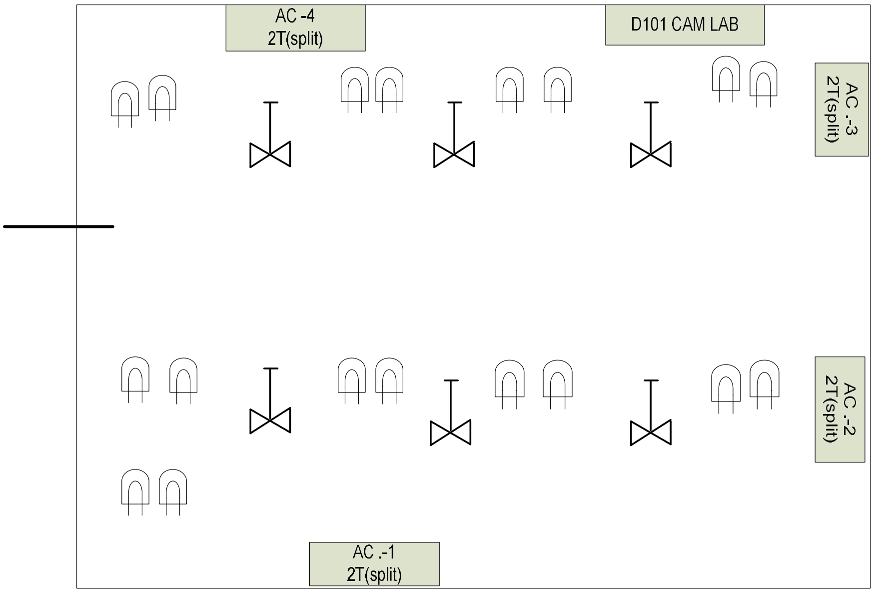


**Figure 3.2 : Layout of Lab**

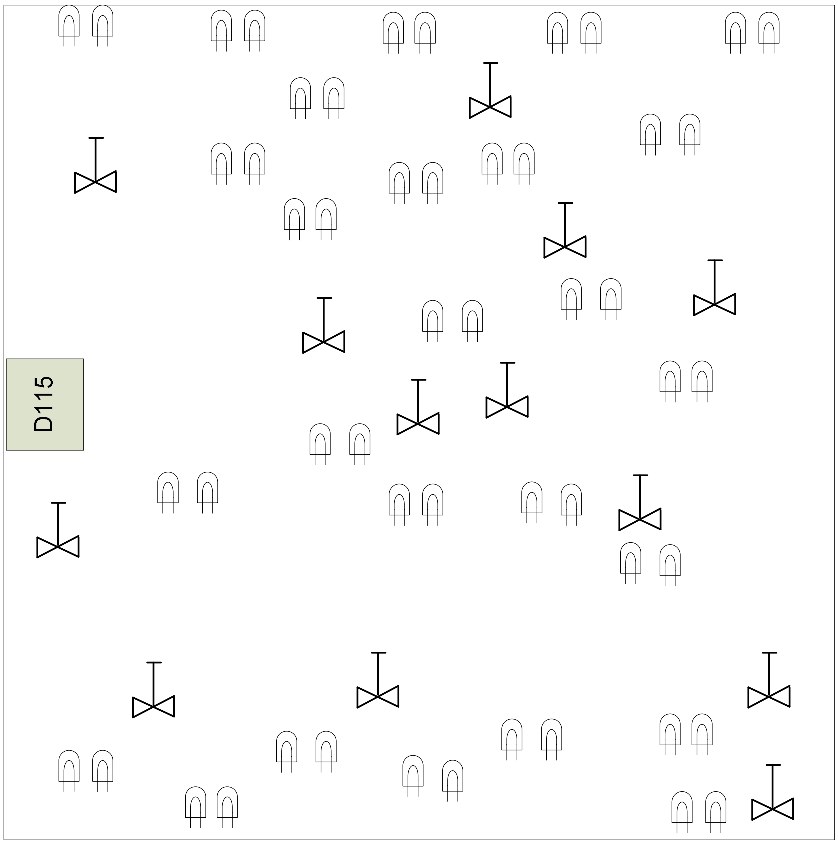


**Figure 2.3: Layout of class room D115**

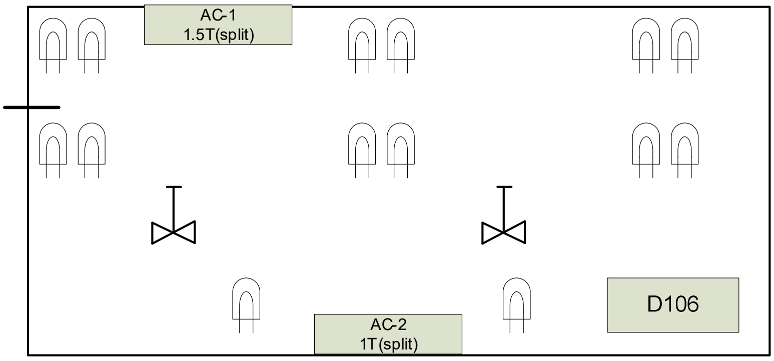


**Figure 3.3: Layout of D106**

## 3.7 Conclusion

This chapter presented the data analysis for fan, ACs and lighting systems for the D- block of TIET, Patiala. The data collected includes the substation data, energy data for variation in the three seasons for the months of January'19, April'19 and August'18. This energy data is taken on hourly basis from 9 AM to 5 PM on all week days. Here, Saturdays and Sundays have not been included because in weekends the energy consumption is not so much. The collected data also includes layout of all the rooms which gives clear picture of number of electrical appliances like fans, tubes and ACs installation.

# CHAPTER 4

# ENERGY EFFICIENCY EVALUATION WITH STRATEGIC AUDITING

## 4.1 Introduction

As the technology is getting advanced day by day, so this leads to replacement of old lighting systems with the energy efficient and cost efficient lighting system. Now a days, every electrical appliance is marked with its star ratings. Star rating is the parameter which tells the quality of appliance and tells that how energy efficient the appliance is. It gives the customers to choose the electrical appliance wisely. So people prefer the high star rating appliances e.g. 3 star, 5 star and so on. Star rating of the electrical appliances does not tell the energy efficiency of appliance but also helpful in cost saving of electricity bills. So the appliance with high star rating will lead to energy bill savings along with its good electrical performance.

Power management is also very important parameter in lighting system. To schedule power management via dimming and controls of lights by the use of various technologies like movement detection, daylight equalization and control technologies. These technologies not only schedule power management but also improves the efficiency of the lighting system.

Lighting system is comprised of two parts: Artificial light source like lamps etc & natural illumination which we get from sunlight. During daytime, the sunlight is used as the main source of lights in buildings. Instead of using artificial source at daytime, Sunlight is used which can save energy. Proper lighting is very important as it does not enhance the task performance only but also improves the appearance of site locality.

Light fixtures are being used in indoor lighting. Proper lighting of a particular area can be judged by the comfortability of the occupants working there. Proper lighting ensures that required number of lumens must be present in lighting system. In the landscape projects also , the lighting has been its intrinsic component. The implementation of efficient lighting system is achieved by incorporating various components like natural daylight, zone control, user control & dual lighting circuit systems. When these all components are incorporated together then it leads to the formation of efficient lighting system. Efficient lighting system does not mean to work efficiently but also to reduce the electricity bills by efficient power consumption.

## 4.2 Data analysis for lighting system

### 4.2.1 Energy data analysis for month of August'18

In this section, the readings of monthly data which are taken i.e. the room measurements and light intensity in the rooms by switching on and switching off of all lights of the rooms will be discussed.

**Table 4.1: Coefficient of utilization using zonal cavity method**

| RCC% | 80 | | | | 70 | | | | 50 | | | 30 | | | 10 | | | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RW% | 70 | 50 | 30 | 0 | 70 | 50 | 30 | 0 | 50 | 30 | 20 | 50 | 30 | 20 | 50 | 30 | 20 | 0 |
| RCR:0 | 1.19 | 1.19 | 1.19 | 1.19 | 1.16 | 1.16 | 1.16 | 1.00 | 1.11 | 1.11 | 1.11 | 1.06 | 1.06 | 1.06 | 1.02 | 1.02 | 1.02 | 1.00 |
| 1 | 1.10 | 1.06 | 1.02 | 0.98 | 1.07 | 1.03 | 1.00 | 0.87 | 0.99 | 0.96 | 0.94 | 0.95 | 0.93 | 0.91 | 0.92 | 0.90 | 0.88 | 0.86 |
| 2 | 1.01 | 0.94 | 0.88 | 0.83 | 0.99 | 0.92 | 0.86 | 0.75 | 0.89 | 0.84 | 0.80 | 0.85 | 0.81 | 0.78 | 0.82 | 0.79 | 0.76 | 0.74 |
| 3 | 0.93 | 0.84 | 0.77 | 0.71 | 0.91 | 0.82 | 0.76 | 066 | 0.79 | 0.74 | 0.69 | 0.77 | 0.72 | 0.68 | 0.74 | 0.70 | 0.67 | 0.65 |
| 4 | 0.86 | 0.75 | 0.68 | 0.61 | 0.84 | 0.74 | 0.67 | 0.58 | 0.72 | 0.65 | 0.60 | 0.70 | 0.64 | 0.59 | 0.67 | 0.63 | 0.59 | 0.57 |
| 5 | 0.80 | 0.68 | 0.60 | 0.54 | 0.78 | 0.67 | 0.60 | 0.52 | 0.65 | 0.58 | 0.53 | 0.63 | 0.57 | 0.53 | 0.62 | 0.56 | 0.52 | 0.50 |
| 6 | 0.74 | 0.62 | 0.54 | 0.48 | 0.73 | 0.61 | 0.54 | 0.46 | 0.60 | 0.53 | 0.47 | 0.58 | 0.52 | 0.47 | 0.56 | 0.51 | 0.47 | 0.45 |
| 7 | 0.69 | 0.57 | 0.49 | 0.43 | 0.68 | 0.56 | 0.48 | 0.42 | 0.55 | 0.48 | 0.43 | 0.53 | 0.47 | 0.42 | 0.52 | 0.46 | 0.42 | 0.40 |
| 8 | 0.65 | 0.52 | 0.44 | 0.39 | 0.63 | 0.52 | 0.44 | 0.38 | 0.50 | 0.44 | 0.39 | 0.49 | 0.43 | 0.38 | 0.48 | 0.42 | 0.38 | 0.36 |
| 9 | 0.61 | 0.48 | 0.41 | 0.35 | 0.60 | 0.48 | 0.40 | 0.35 | 0.47 | 0.40 | 0.35 | 0.46 | 0.39 | 0.35 | 0.45 | 0.39 | 0.35 | 0.33 |
| 10 | 0.57 | 0.45 | 0.37 | 0.32 | 0.56 | 0.44 | 0.37 | 0.32 | 0.43 | 0.37 | 0.32 | 0.42 | 0.36 | 0.32 | 0.42 | 0.36 | 0.32 | 0.30 |

Table 4.1 shows the variation in coefficient of utilization when effective floor cavity reflectance is taken as 20%. Table 16 shows readings of monthly data which includes the room measurements light intensity and various important parameters of energy efficiency evaluation. In the rooms by switching on and switching off of all lights of the rooms the light intensity is observed and it is discussed below.

**Table 4.2: Energy efficiency evaluation of lighting system of D-block of august'18**

| Room No. | RI | Eav | RCR | Lumens | ILE | ILER | IMP task | IMP Non task | Eav task | Eav non task | DF | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D106 | 0.70 | 493.56 | 0.47 | 7355.84 | 15.01 | 0.33 | 5.6 | 2.4 | 422.5 | 510 | 0.83 | 5 |
| D104 | 1.89 | 1231.42 | 0.18 | 130485.41 | 100.37 | 2.18 | 14.4 | 3.6 | 1259.57 | 786.50 | 1.60 | 32 |
| D107 | 0.70 | 814.10 | 0.47 | 12133.13 | 93.33 | 2.03 | 5.6 | 2.4 | 643.83 | 537.50 | 1.20 | 5 |
| D108 | 0.70 | 585.79 | 0.47 | 8730.44 | 67.16 | 1.46 | 5.6 | 2.4 | 558.17 | 383.50 | 1.46 | 5 |
| D109 | 0.70 | 693.79 | 0.47 | 10340.04 | 68.93 | 1.46 | 5.6 | 2.4 | 629.83 | 286.50 | 2.20 | 5 |
| D110 | 0.70 | 693.79 | 0.47 | 10340.04 | 68.93 | 1.46 | 5.6 | 2.4 | 629.83 | 286.50 | 2.20 | 5 |
| D101 | 1.48 | 108 | 0.23 | 7332.53 | 8.15 | 0.18 | 10.8 | 7.2 | 102.55 | 68.86 | 1.49 | 20 |
| D102 | 1.48 | 254.02 | 0.19 | 17248.43 | 21.56 | 0.47 | 10.8 | 7.2 | 242.36 | 189.72 | 1.28 | 20 |
| D116 | 1.92 | 621.43 | 0.19 | 120326.51 | 46.28 | 1.07 | 13.5 | 4.5 | 781.36 | 448.25 | 1.74 | 58 |
| D115 | 1.92 | 805.68 | 0.41 | 156002 | 60.00 | 1.30 | 13.5 | 4.5 | 1059.57 | 613 | 1.73 | 58 |
| Rsch. Lab | 0.82 | 236.95 | 0.20 | 7258.51 | 18.15 | 0.39 | 4.8 | 3.2 | 219.40 | 194.67 | 1.13 | 9 |
| D201 | 1.73 | 1511.56 | 0.20 | 149848.70 | 146.91 | 32.65 | 13.5 | 4.5 | 1361.07 | 247.25 | 5.50 | 30 |
| D202 | 1.73 | 988.63 | 0.28 | 98007.64 | 96.09 | 2.09 | 13.5 | 4.5 | 1361.29 | 825.50 | 1.65 | 30 |
| D203 | 1.20 | 2478.17 | 0.28 | 125252.90 | 379.55 | 8.25 | 13.5 | 4.5 | 2665.57 | 650 | 4.10 | 15 |
| D204 | 1.20 | 1797.55 | 0.73 | 90852.83 | 275.31 | 5.99 | 13.5 | 4.5 | 2399.93 | 1433.75 | 1.67 | 15 |
| Cabin near str. Lab | 0.51 | 317.74 | 0.73 | 4675.54 | 23.38 | 0.51 | 4.8 | 3.2 | 294.20 | 261.13 | 1.13 | 5 |
| Str.Lab | 1.59 | 224.21 | 0.25 | 100611.62 | 47.46 | 1.03 | 10.8 | 7.2 | 248.18 | 260.29 | 0.95 | 136 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D120 | 0.41 | 108.43 | 0.93 | 1310.25 | 13.10 | 0.28 | 5.6 | 2.4 | 104 | 105 | 0.99 | 4 |
| Dr. Tapas cabin | 0.66 | 1093.18 | 0.58 | 40619.15 | 270.79 | 5.89 | 5.6 | 2.4 | 1142.83 | 2231 | 0.51 | 12 |
| D112(Lab) | 1.68 | 611.71 | 0.20 | 51450.3 | 64.31 | 1.39 | 10.8 | 7.2 | 707.36 | 585 | 1.21 | 25 |
| Transp Lab | 1.41 | 291.82 | 0.26 | 38871.59 | 64.79 | 1.41 | 10.8 | 7.2 | 253.36 | 263.57 | 0.96 | 40 |
| D117 | 0.61 | 1036.37 | 0.63 | 35897.29 | 358.97 | 7.80 | 5.2 | 2.8 | 959.60 | 1103.67 | 0.87 | 11 |
| D114 | 0.41 | 358.99 | 0.94 | 5322.21 | 88.70 | 1.93 | 4 | 4 | 338.50 | 363 | 0.93 | 5 |
| D113 | 0.41 | 358.99 | 0.94 | 5321.35 | 88.69 | 1.93 | 4 | 4 | 338.50 | 376 | 0.90 | 5 |
| D111 | 1.05 | 440.86 | 0.32 | 15238.38 | 126.99 | 2.76 | 15.3 | 2.7 | 616.07 | 604.67 | 1.02 | 11 |
| D123 | 0.41 | 141.05 | 0.93 | 1704.37 | 17.04 | 0.37 | 5.6 | 2.4 | 125.00 | 142.50 | 0.88 | 4 |
| Dr. T.P cabin | 0.71 | 788.62 | 0.46 | 12279.15 | 55.81 | 1.21 | 5.6 | 2.4 | 827.67 | 1766.50 | 0.47 | 5 |
| D103 | 0.41 | 30.24 | 0.93 | 365.41 | 3.65 | 0.08 | 5.6 | 2.4 | 28.33 | 36 | 0.79 | 4 |
| D118 | 1.39 | 252.07 | 0.24 | 16155.15 | 16.48 | 0.36 | 14.4 | 3.6 | 216.14 | 236.25 | 0.91 | 19 |
| Room near stairs | 0.51 | 181.87 | 0.73 | 2676.27 | 6.69 | 0.15 | 5.6 | 2.4 | 153.50 | 107.50 | 1.43 | 5 |
| D119 | 0.41 | 273.89 | 0.93 | 3309.55 | 11.03 | 0.24 | 5.6 | 2.4 | 250.00 | 169 | 1.48 | 4 |
| D121 | 0.67 | 309.74 | 0.51 | 4524.99 | 11.31 | 0.25 | 5.6 | 2.4 | 272.33 | 223 | 1.22 | 5 |
| Corridor1 | 1.28 | 620.57 | 0.26 | 281189.8 | 562.38 | 12.23 | 13.5 | 4.5 | 566.43 | 448.25 | 1.26 | 10 |
| Corridor2 | 1.20 | 527.26 | 0.31 | 60937.82 | 406.25 | 8.83 | 13.5 | 4.5 | 522.86 | 214.25 | 2.44 | 3 |

### 4.2.2 Energy data analysis for month of January'19

In this section, the readings of monthly data which are taken i.e. the room measurements light intensity and various important parameters of energy efficiency evaluation in the rooms by switching on and switching off of all lights of the rooms will be discussed.

**Table 4.3: Energy efficiency evaluation of lighting system of D-block of January'19**

| Room No. | RI | Eav | RCR | Lumens | ILE | ILER | IMP task | IMP non task | Eav task | Eav non task | DF | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D106 | 0.70 | 70.88 | 0.47 | 1056.29 | 2.16 | 0.05 | 5.6 | 2.4 | 57.50 | 90 | 0.64 | 5 |
| D104 | 1.89 | 492.96 | 0.18 | 52235.87 | 40.18 | 0.87 | 14.4 | 3.6 | 417.57 | 592.5 | 0.71 | 32 |
| D107 | 0.70 | 80.19 | 0.47 | 1195.12 | 9.19 | 0.19 | 5.6 | 2.4 | 66.83 | 96.5 | 0.69 | 5 |
| D108 | 0.70 | 67.51 | 0.47 | 1005.99 | 7.74 | 0.17 | 5.6 | 2.4 | 66.50 | 50.50 | 1.32 | 5 |
| D109 | 0.70 | 215.73 | 0.47 | 3215.17 | 21.43 | 0.47 | 5.6 | 2.4 | 210.33 | 168 | 1.25 | 5 |
| D110 | 0.70 | 215.73 | 0.47 | 3215.17 | 21.43 | 0.47 | 5.6 | 2.4 | 210.33 | 168 | 1.25 | 5 |
| D101 | 1.48 | 118.20 | 0.23 | 8025.05 | 8.92 | 0.19 | 10.8 | 7.2 | 91.36 | 137.86 | 0.66 | 20 |
| D102 | 1.48 | 132.72 | 0.19 | 9012.08 | 11.27 | 0.24 | 10.8 | 7.2 | 121.18 | 125.57 | 0.97 | 20 |
| D116 | 1.92 | 749.22 | 0.19 | 145069.81 | 55.79 | 1.21 | 13.50 | 4.5 | 688.14 | 713.25 | 0.96 | 58 |
| D115 | 1.92 | 518.52 | 0.41 | 100399.90 | 38.62 | 0.84 | 13.5 | 4.5 | 463.64 | 537.75 | 0.86 | 58 |
| Rsch Lab | 0.82 | 232.47 | 0.20 | 7121.21 | 17.80 | 0.39 | 4.8 | 3.2 | 239.40 | 175 | 1.37 | 9 |
| D201 | 1.73 | 807.66 | 0.20 | 80067.06 | 78.49 | 17.44 | 13.5 | 4.5 | 783.93 | 621.50 | 1.26 | 30 |
| D202 | 1.73 | 910.14 | 0.28 | 90226.37 | 88.46 | 1.92 | 13.5 | 4.5 | 790.07 | 1027 | 0.77 | 30 |
| D203 | 1.20 | 257.70 | 0.28 | 13024.81 | 39.47 | 0.86 | 13.5 | 4.5 | 241.29 | 229.25 | 1.05 | 15 |
| D204 | 1.20 | 800.10 | 0.73 | 40439.08 | 122.54 | 2.66 | 13.5 | 4.5 | 734.64 | 762.50 | 0.96 | 15 |
| Cabin near str. Lab | 0.51 | 365.18 | 1.04 | 5375.08 | 26.88 | 0.58 | 5.6 | 2.4 | 338.13 | 325.67 | 1.04 | 5 |
| Str. Lab | 1.59 | 958.98 | 0.25 | 430335 | 202.99 | 4.41 | 10.8 | 7.2 | 1032.72 | 660.43 | 1.56 | 136 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D120 | 0.41 | 105.17 | 0.93 | 1270.77 | 12.71 | 0.28 | 5.6 | 2.4 | 96.50 | 100 | 0.97 | 4 |
| Dr.Tapas cabin | 0.66 | 96.26 | 0.58 | 3576.55 | 23.84 | 0.52 | 5.6 | 2.4 | 98 | 62.50 | 1.57 | 12 |
| D112 (Lab) | 1.68 | 270.06 | 0.20 | 22714.39 | 28.39 | 0.62 | 10.8 | 7.2 | 228.27 | 284.29 | 0.80 | 25 |
| Transp Lab | 1.41 | 737.52 | 0.26 | 98241.95 | 163.74 | 3.56 | 10.8 | 7.2 | 587 | 833.57 | 0.70 | 40 |
| D117 | 0.61 | 602.78 | 0.63 | 20878.67 | 208.79 | 4.54 | 5.2 | 2.8 | 506.40 | 644.33 | 0.79 | 11 |
| D114 | 0.41 | 83.70 | 0.94 | 1240.89 | 20.68 | 0.45 | 4 | 4 | 67.50 | 87.50 | 0.77 | 5 |
| D113 | 0.41 | 81.95 | 0.94 | 1214.67 | 20.24 | 0.44 | 4 | 4 | 68.25 | 83.50 | 0.82 | 5 |
| D111 | 1.05 | 220.86 | 0.32 | 7634.12 | 63.62 | 1.38 | 15.3 | 2.7 | 197.67 | 181 | 1.09 | 11 |
| D123 | 0.41 | 116.10 | 0.93 | 1402.90 | 14.03 | 0.31 | 5.6 | 2.4 | 103.67 | 119 | 0.87 | 4 |
| Dr.T.P cabin | 0.71 | 71.82 | 0.46 | 1118.27 | 5.08 | 0.11 | 5.6 | 2.4 | 59.50 | 87.50 | 0.68 | 5 |
| D103 | 0.41 | 166.73 | 0.93 | 2014.64 | 20.15 | 0.44 | 5.6 | 2.4 | 138 | 203.50 | 0.68 | 4 |
| D118 | 1.39 | 177.84 | 0.24 | 11397.66 | 11.63 | 0.25 | 14.4 | 3.6 | 158.29 | 187 | 0.85 | 19 |
| Room near stairs | 0.51 | 1004.4 | 0.73 | 14779.91 | 36.95 | 0.80 | 5.6 | 2.4 | 928.67 | 934 | 0.99 | 5 |
| D119 | 0.41 | 162.81 | 0.93 | 1967.33 | 4.92 | 0.11 | 5.6 | 2.4 | 146.33 | 164 | 0.89 | 4 |
| D121 | 0.67 | 131.35 | 0.51 | 1918.94 | 4.79 | 0.10 | 5.6 | 2.4 | 120.83 | 112 | 1.11 | 5 |
| Corridor1 | 1.28 | 527.31 | 0.26 | 238933.1 | 477.87 | 10.39 | 13.5 | 4.5 | 355.57 | 314.75 | 1.13 | 10 |
| Corridor2 | 1.20 | 83.70 | 0.31 | 9673.66 | 64.49 | 1.40 | 13.5 | 4.5 | 72.50 | 74.25 | 0.98 | 3 |

### 4.2.3 Energy data analysis for the month of April'19

In this section, the readings of monthly data which are taken i.e. the room measurements light intensity and various important parameters of energy efficiency in the rooms by switching on and switching off of all lights of the rooms will be discussed.

**Table 4.4: Energy efficiency evaluation of lighting system of D-block of April'19**

| Room No | RI | Eav | RCR | Lumens | ILE | ILER | IMP Task | IMP non-task | $E_{av}$ task | $E_{av}$ non task | DF | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D106 | 0.70 | 868.19 | 0.47 | 12939.13 | 26.41 | 0.57 | 5.6 | 2.4 | 764.67 | 921.50 | 0.82 | 5 |
| D104 | 1.89 | 1601.4 | 0.18 | 169692.8 | 130.53 | 2.84 | 14.4 | 3.6 | 1273.21 | 1735 | 0.73 | 32 |
| D107 | 0.70 | 1616.1 | 0.47 | 24085.98 | 185.28 | 4.02 | 5.6 | 2.4 | 1562.33 | 1724.50 | 0.91 | 5 |
| D108 | 0.70 | 224.42 | 0.47 | 3344.74 | 25.73 | 0.56 | 5.6 | 2.4 | 216.67 | 326 | 0.66 | 5 |
| D109 | 0.70 | 475.85 | 0.47 | 7091.88 | 47.28 | 1.03 | 5.6 | 2.4 | 508.33 | 654.50 | 0.78 | 5 |
| D110 | 0.70 | 475.85 | 0.47 | 7091.88 | 47.28 | 1.03 | 5.6 | 2.4 | 508.33 | 654.50 | 0.78 | 5 |
| D101 | 1.48 | 1139.18 | 0.23 | 77343.57 | 85.94 | 1.87 | 10.8 | 7.2 | 1245.73 | 1630.57 | 0.76 | 20 |
| D102 | 1.48 | 618.84 | 0.19 | 42021.04 | 52.53 | 1.14 | 10.8 | 7.2 | 653.64 | 555.86 | 1.18 | 20 |
| D116 | 1.92 | 2723.33 | 0.19 | 527311.90 | 202.81 | 4.41 | 13.5 | 4.5 | 2314.64 | 2639 | 0.88 | 58 |
| D115 | 1.92 | 1840.32 | 0.41 | 356337.10 | 137.05 | 2.98 | 13.5 | 4.5 | 2110.07 | 2286 | 0.92 | 58 |
| Rsch Lab | 0.82 | 1055.1 | 0.20 | 32322.51 | 80.81 | 1.76 | 4.8 | 3.2 | 977 | 928.67 | 1.05 | 9 |
| D201 | 1.73 | 1469.66 | 0.20 | 145694.60 | 142.84 | 31.74 | 13.5 | 4.5 | 964.64 | 1100 | 0.88 | 30 |
| D202 | 1.73 | 1383.69 | 0.28 | 137172.20 | 134.48 | 2.92 | 13.5 | 4.5 | 847 | 654.75 | 1.29 | 30 |
| D203 | 1.20 | 1017.36 | 0.28 | 51419.95 | 155.82 | 3.38 | 13.5 | 4.5 | 885.21 | 610.75 | 1.45 | 15 |
| D204 | 1.20 | 1127.52 | 0.73 | 56987.72 | 172.69 | 3.75 | 13.5 | 4.5 | 1530.64 | 1261.25 | 1.21 | 15 |
| Cabin near str.. lab | 0.51 | 317.74 | 0.25 | 376.55 | 1.88 | 0.04 | 4.8 | 3.2 | 281.88 | 61.11 | 4.61 | 5 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Structure Lab | 1.59 | 1419.55 | 0.93 | 637013.10 | 300.47 | 6.53 | 10.8 | 7.2 | 1350.09 | 1412.14 | 0.96 | 136 |
| D120 | 0.41 | 830.30 | 0.93 | 10033.05 | 100.33 | 2.18 | 5.6 | 2.4 | 739.67 | 676.50 | 1.09 | 4 |
| Dr.Tapas cabin | 0.66 | 400.25 | 0.58 | 14872.02 | 99.15 | 2.16 | 5.6 | 2.4 | 349.67 | 383 | 0.91 | 12 |
| D112(Lab) | 1.68 | 1251.72 | 0.20 | 105280.5 | 131.60 | 2.86 | 10.8 | 7.2 | 1074.64 | 1091.14 | 0.98 | 25 |
| TranspLab | 1.41 | 6978.7 | 0.26 | 929609.3 | 1549.3 | 33.68 | 10.8 | 7.2 | 3600 | 5730.29 | 0.63 | 40 |
| D117 | 0.61 | 1378.5 | 0.63 | 47748.33 | 477.48 | 10.38 | 5.2 | 2.8 | 1276.4 | 659.67 | 1.93 | 11 |
| D114 | 0.41 | 510.41 | 0.94 | 7567.02 | 126.12 | 2.74 | 4 | 4 | 416.25 | 518.25 | 0.80 | 5 |
| D113 | 0.41 | 472.82 | 0.94 | 7008.69 | 116.81 | 2.54 | 4 | 4 | 371 | 537.25 | 0.69 | 5 |
| D111 | 1.05 | 1234.8 | 0.32 | 42683.88 | 355.69 | 7.73 | 15.3 | 2.7 | 1209.27 | 1208 | 1.00 | 11 |
| D123 | 0.41 | 207.14 | 0.93 | 2503.04 | 25.03 | 0.54 | 5.6 | 2.4 | 203 | 153.50 | 1.32 | 4 |
| Dr.T.P cabin | 0.71 | 304.34 | 0.46 | 4738.79 | 21.54 | 0.47 | 5.6 | 2.4 | 293.33 | 353.50 | 0.83 | 5 |
| D103 | 0.41 | 308.88 | 0.93 | 3732.38 | 37.32 | 0.81 | 5.6 | 2.4 | 263.33 | 172.50 | 1.53 | 4 |
| D118 | 1.39 | 1187.3 | 0.24 | 76096.71 | 77.65 | 1.69 | 14.4 | 3.6 | 1047.57 | 811.25 | 1.29 | 19 |
| Room near stairs | 0.51 | 1235.5 | 0.73 | 18180.88 | 45.45 | 0.99 | 5.6 | 2.4 | 1034 | 772.50 | 1.34 | 5 |
| D119 | 0.41 | 989.71 | 0.93 | 11959.27 | 29.89 | 0.65 | 5.6 | 2.4 | 889.33 | 944.50 | 0.94 | 4 |
| D121 | 0.67 | 1070.49 | 0.51 | 15638.68 | 39.09 | 0.85 | 5.6 | 2.4 | 970 | 809.50 | 1.19 | 5 |
| Corridor1 | 1.28 | 1423.66 | 0.26 | 645082.60 | 1290.17 | 28.05 | 13.5 | 4.5 | 1199.71 | 86.25 | 1.40 | 10 |
| Corridor2 | 1.20 | 893.60 | 0.31 | 103277.3 | 688.52 | 14.97 | 13.5 | 4.5 | 1304.64 | 382.50 | 3.41 | 3 |

## 4.3 Data analysis and calculations of CFM using regression method for fans

This data gives information about number of fans which should be installed as per the BEE guidelines.

$$\hat{y} = mx + b \tag{18}$$

$$m = \frac{n\sum xy \quad (\sum x)(y)}{n\sum(x^2) - n(\sum x)^2} \tag{19}$$

$$b = \frac{\sum y}{n} - m\frac{\sum x}{n} \tag{20}$$

Where 'm' represents slope of the line and b represents the y-intercept ( the y-value for which x is 0). $\hat{y}$ is the predicted value of y. Linear regression line is the representation of equation (20).

Table 4.5 shows the mathematical calculations for the analysis of fans. With the help of this table, the regression curve can be obtained which shows different variations in CFM. Hence the most suitable CFM will be obtained which is very important parameter for the data analysis for fans.

**Table 4.5 :Mathematical calculations for analysis of fans**

| S. No. | Room Area (x) | CFM Recommended | Average CFM (y) | x*y | $x^2$ | Linearized value of new CFM y=23.72x+2841.94 |
|---|---|---|---|---|---|---|
| 1 | 36 | 3000-4500 | 3750 | 135000 | 1296 | 3695.86 |
| 2 | 100 | 4000-5500 | 4750 | 475000 | 10000 | 5213.94 |
| 3 | 144 | 6200-7500 | 6850 | 986400 | 20736 | 6257.62 |
| 4 | 225 | 7000-9000 | 8000 | 1800000 | 50625 | 8178.94 |
| Sum | 505 | | 23350 | 3396400 | 82657 | |

m=23.72723305

c=2841.936828

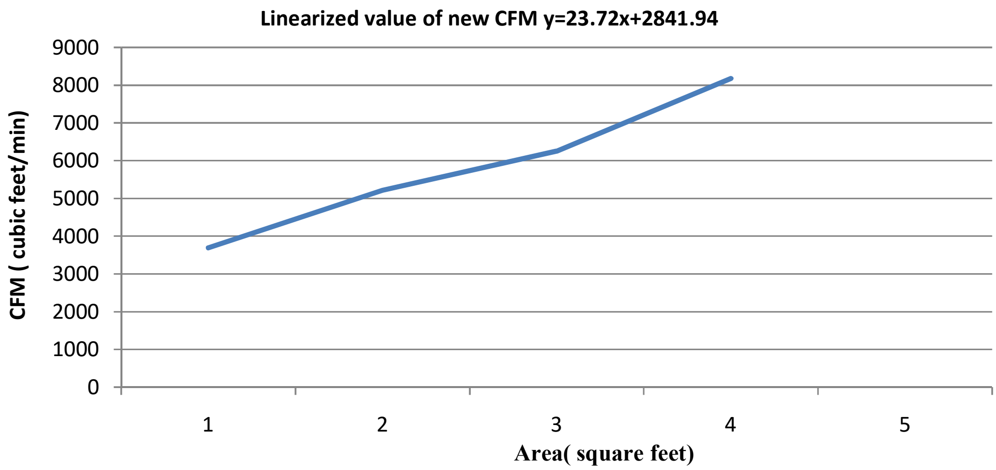


**Fig. 4.1 : CFM Regression curve**

Fig. 4.1 shows the graph between area of a room (in square feet) and the CFM (cubic feet/min). This curve is very important curve as it gives the variation of CFM w.r.t. the area of the room. This helps in determining the number of fans which should be installed as per the BEE guidelines.

Table 4.6 shows the various important parameters which are being calculated with the help of room data. By doing various calculations the important results are obtained. The result analysis gives the information of the number of fans which should be installed in a room according to the area and CFM. Here it can be observed that the number of fans which should be installed in a room is different in different rooms because it depends upon area of a room. However, if the area of two rooms are similar then number of fans which should be installed will be similar also.

**Table 4.6: Detailed information & data analysis of fans**

| Room No. | Area | | Volume | | Fan Size (37" to 48") | |
|---|---|---|---|---|---|---|
| | $ft^2$ | $m^2$ | $ft^3$ | $M^3$ | CFM | Fan |
| D106 | 160.34 | 14.89 | 1349.51 | 38.23 | 6645.19 | 1.58 |
| D104 | 1140 | 105.91 | 10069.62 | 285.21 | 29882.74 | 7.11 |
| D107 | 160.34 | 14.89 | 1349.51 | 38.23 | 6645.19 | 1.58 |
| D108 | 160.34 | 14.89 | 1349.51 | 38.23 | 6645.19 | 1.58 |
| D109 | 160.34 | 14.89 | 1349.57 | 38.23 | 6645.19 | 1.58 |
| D110 | 160.34 | 14.89 | 1349.57 | 38.23 | 6645.19 | 1.58 |
| D101(CAM LAB) | 730.43 | 67.86 | 6634.49 | 187.91 | 20167.72 | 4.80 |
| D102(CAD LAB -2) | 730.53 | 67.87 | 6635.37 | 187.94 | 20170.03 | 4.80 |
| D116 | 2083.13 | 193.53 | 24649.62 | 698.17 | 52253.67 | 12.44 |
| D115 | 2083.13 | 193.53 | 24649.62 | 698.17 | 52253.67 | 12.44 |
| Research Lab | 329.56 | 30.62 | 2966.04 | 84.01 | 10659.10 | 2.54 |
| D201 | 1066.53 | 99.08 | 10043.51 | 284.47 | 28140.03 | 6.700 |
| D202 | 1066.53 | 99.08 | 10043.51 | 284.47 | 28140.03 | 6.700 |
| D203 | 543.76 | 50.52 | 5120.56 | 145.03 | 15739.85 | 3.75 |
| D204 | 543.76 | 50.52 | 5120.56 | 145.03 | 15739.85 | 3.75 |
| Cabin near str. Lab | 158.31 | 14.71 | 1965.76 | 55.68 | 6597.09 | 2 |
| Structure Lab | 4827.75 | 448.51 | 77646.15 | 2199.24 | 117356.20 | 27.94 |
| D120 | 130 | 12.077 | 1798.29 | 50.93 | 5925.54 | 1.41 |
| Dr. Tapas cabin | 399.75 | 37.14 | 5529.74 | 156.62 | 12324.01 | 2.93 |
| D112(Lab) | 904.88 | 84.06 | 8068.41 | 228.53 | 24305.58 | 5.79 |
| Transportation Lab | 1433.08 | 133.14 | 18510.54 | 524.29 | 36834.63 | 8.77 |
| D117 | 372.65 | 34.62 | 5310.19 | 150.41 | 11681.08 | 2.78 |
| D114 | 159.49 | 14.82 | 2299.48 | 65.13 | 6625.23 | 1.58 |
| D113 | 159.47 | 14.82 | 2299.11 | 65.12 | 6624.62 | 1.58 |
| D111(MED Office) | 371.87 | 34.55 | 3408.77 | 96.55 | 11662.67 | 2.78 |
| D123 | 130 | 12.08 | 1798.29 | 50.93 | 5925.54 | 1.41 |
| Dr. T.P cabin | 167.51 | 15.56 | 1409.96 | 39.94 | 6815.37 | 1.62 |
| D103 | 130 | 12.08 | 1797.90 | 50.92 | 5925.54 | 0.68 |
| D118 | 689.49 | 64.06 | 6435.10 | 182.27 | 19196.87 | 4.57 |
| Room near stairs | 158.31 | 14.71 | 1965.76 | 55.68 | 6597.09 | 1.57 |
| D119 | 130 | 12.08 | 1798.29 | 50.93 | 5925.54 | 1.41 |
| D121 | 157.17 | 14.60 | 1480.05 | 41.92 | 6569.95 | 1.56 |

## 4.4 Data analysis for Air Conditioners

Table 4.7 gives information about the number of ACs which are recommended as per BEE guidelines. There are total three recommendations given over here. Area method gives two criterions and volume method gives one criteria. This not only leads to huge power savings but also it leads to less electricity bills along with enhancement of energy efficiency which is the biggest issue of concern nowadays.

**Table 4.7: Detailed information of AC**

| Room No. | Recommended BTU/kW in different room | | AC size in tonnes in different methods based on | | | |
|---|---|---|---|---|---|---|
| | | | Area | | | Volume |
| | BTU Recommended | kW | BTU | Criterion-1 | Criterion-2 | Criterion-3 |
| D106 | 6000 | 1.76 | 4008.49 | 0.33 | 1.27 | 1.35 |
| D104 | 17700 | 5.19 | 28500 | 2.38 | 3.38 | 10.07 |
| D101(CAM LAB) | 15000 | 4.40 | 18260.73 | 1.52 | 2.70 | 6.63 |
| D102(CAD LAB -2) | 15000 | 4.40 | 18263.17 | 1.52 | 2.70 | 6.64 |
| Research Lab | 7250 | 2.12 | 8239 | 0.69 | 1.82 | 2.97 |
| D201 | 17700 | 5.19 | 26663.24 | 2.22 | 3.26 | 10.04 |
| D202 | 17700 | 5.19 | 26663.24 | 2.22 | 3.27 | 10.04 |
| D203 | 10500 | 3.08 | 13593.92 | 1.13 | 2.33 | 5.12 |
| D204 | 10500 | 3.08 | 13593.92 | 1.13 | 2.33 | 5.12 |
| cabin in str. Lab | 6000 | 1.76 | 3957.79 | 0.33 | 1.26 | 1.97 |
| D112(Lab) | 15000 | 4.40 | 22621.88 | 1.89 | 3.01 | 8.07 |
| Dr.T.P cabin | 6000 | 1.76 | 4187.84 | 0.35 | 1.29 | 1.41 |
| D118 | 12500 | 3.66 | 17237.49 | 1.44 | 2.63 | 6.44 |
| D119 | 5000 | 1.47 | 3250 | 0.27 | 1.14 | 1.79 |

## 4.5 Uniform layout of sample rooms in D-block

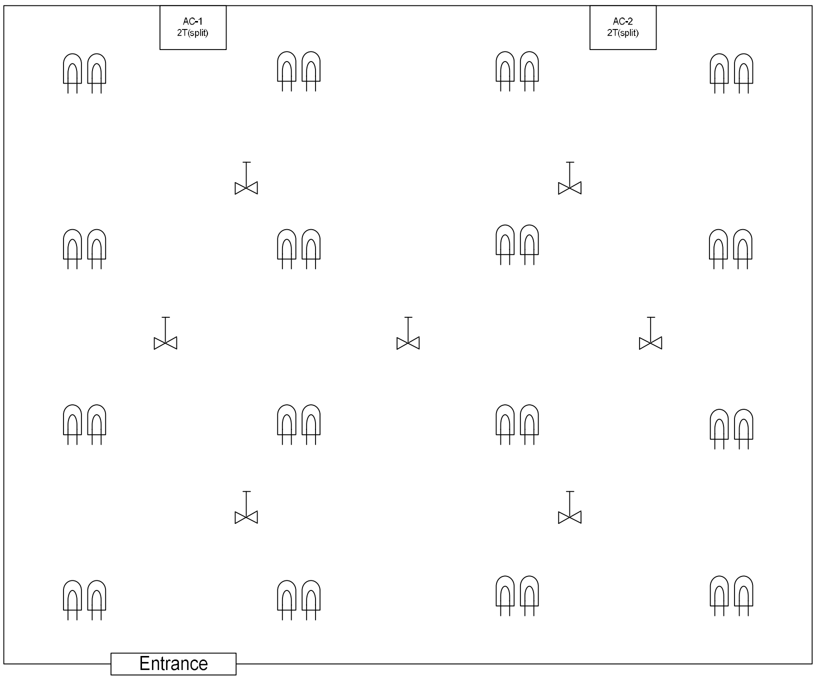


**Figure 4.2 : Layout of Seminar room (D104) for uniform distribution of components**

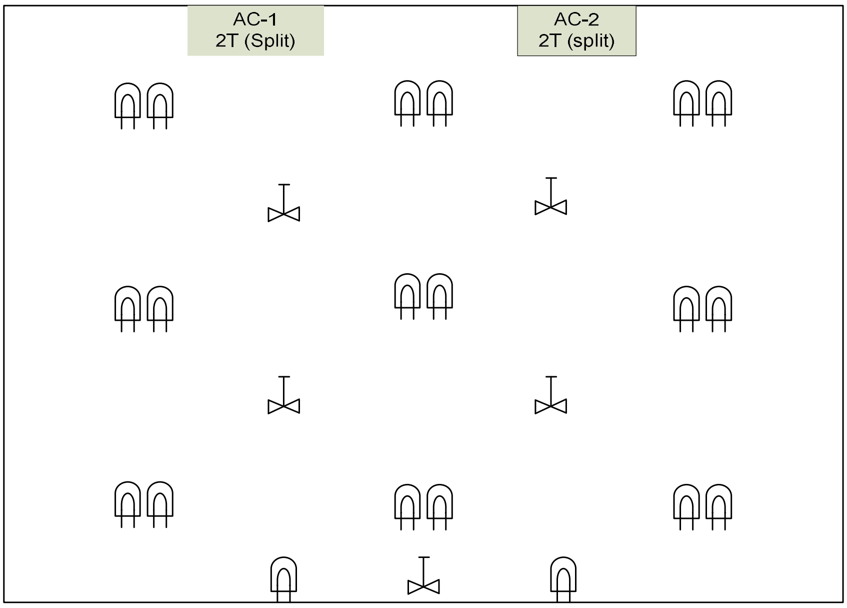


**Figure 4.3 : Layout of Lab (D101) for uniform distribution of components**

These figures describe the uniform layout of D- Block of TIET, Patiala. In these figures, the uniform layout of one seminar room and one lab has been shown. These figures gives the clear picture of number of electrical appliances which should be installed in a particular room as per the BEE guidelines.

## 4.6 Conclusion

This chapter describes the energy efficiency evaluation with strategic energy auditing techniques. In chapter 3, the actual data has been collected and in this chapter the data recommendations have been given as per the strategic energy auditing techniques. The difference in both actual & recommended data will give the power savings along with the enhanced energy efficiency with reduced monthly electricity bills.

# CHAPTER 5
# ENERGY EFFICIENCY EVALUATION WITH DSM

## 5.1 Introduction

Demand side management (DSM) is a cost effective mean to reduce peak load demand of power utilities by reshaping the load profile. However, in commercial and residential buildings the load shifting is rare rather it needs to manage according to the requirement which depends upon the surrounding environmental condition and number of persons involved in a specific area. This allows operating the number of power components based on the framework designed for their operating schedule. The operating schedule of various components may vary with the application and the recommendation for specific purposes. In this scenario, operating schedule applicable under some circumstances, at the same time, may be different than other system of same size. Therefore, the implementation of DSM schemes should have flexibility in order to meet the objective of power saving and hence to improve the energy efficiency without affecting the comfort level.

In the mid of $18^{th}$ century, the origin of DSM was made by the electricity utilities of USA. In simple words, DSM means reduction in energy consumption which leads to reduction in electricity bills. For this DSM provide incentives to consumers so that consumers can get motivated for using less power at peak load. It helps them to realize the peak load hours so that they can consume less energy at that time and shifts their energy usage at off load hours. This does not only help in uninterrupted supply but also it reduces the risk of complete blackouts which are caused due to overloading. In initial days since DSM came into picture, it was known as the set of programmes made by the electricity industries which were planned, implemented & monitored to make the load curve and to do modifications in it. DSM has set benchmarks to the various technologies which are developed to incorporate DSM based technologies. Nowadays DSM is most famous because of its numerous advantages  like load curve, load shifting, load clipping, prevent the hazard of blackouts, system reliability, system security, uninterrupted supply, reduction in fuel cost, reduction in electricity bills and above all enhancement in energy efficiency. DSM does not only make consumers to reduce energy use at peak demand but it also provides incentives to them to grab the opportunity of savings in their monthly electricity bills.

1. **Load curves:** DSM makes it possible to plot the electricity demand with respect to time on hourly basis. This results in load graph which gives complete details of peak and non-peak hours i.e. it gives us the time that when the energy demand is maximum or not and hence load can be adjusted accordingly.

2. **Load shifting:** With the help of load curves, the load pattern can be adjusted very easily. So the peak and off-peak hours can also be identified. So at the time of peak load demand, the load can be shifted to off peak hours.

3. **Risk of Blackouts:** At the time of peak load hours, if the load is not getting shifted, this results into overloading which puts burden on the power system and this results in frequency drop. This results into complete shut-down of system means complete blackouts. The system will keep in this position until it gets completely stable again. This problem does not occur in DSM because before getting overloaded, load is shifted.

4. **Reliability & Security:** DSM based system is completely reliable as there is no risk of blackouts, System shut downs and damage to electrical machinery due to overloading. Hence system is reliable and secure.

5. **Uninterrupted power supply:** Since the load is shifted accordingly , there is no power cuts as the system does not get bulky and does not get overloaded.

6. **Improvement in Energy Efficiency:** As the power supply does not get interrupted . So this results in better utilisation of electrical machinery and equipment used. The continuous working of system smoothly will make the system better and hence increase its energy efficiency which further reduces power losses and results in power savings of the consumers. This also results in reduced electricity bills along with the fuel costs.

DSM based techniques are very useful and are being used in Industrial, Commercial &Residential sectors. DSM based auditing strategies are very helpful and are very popular nowadays as they first analyse the actual data and then purpose different recommendations which includes numerous calculations and after these recommendations, it gives results which is the comparison between already existing data and data recommended as per by DSM based energy auditing strategies. TIET is one of the examples of commercial sector. Energy auditing of D- block of TIET has been carried out where already existing data like number of fans, lights, ACs, temperature, humidity, luminous intensity and number of people has been analysed. After this, the DSM based strategic auditing techniques have been applied and recommended data has been obtained. The difference between already existing data and recommended data as per by DSM based strategic auditing techniques will give power savings of fans, lights and ACs ( in hourly basis from 9AM to 5 PM)of all rooms in D- block of TIET. The recommended data which has been calculated , if followed, will result in huge power savings of components i.e. fans, lights, ACs. This also results in reduced monthly electricity bills and the biggest advantage is that it enhances the energy efficiency of the components. This also results in reduced power losses which increase the component life along with huge power savings. Enhanced energy efficiency means maximum utilization of components at lower cost without compromising the comfort level.

### 5.2 Operating schedules for DSM

In commercial and residential buildings the load shifting is rare rather it needs to manage according to the requirement which depends upon the surrounding environmental condition and number of persons involved in a specific area. This allows operating the number of power components based on the framework designed for their operating schedule. The operating schedule of various components may vary with the application and the recommendation for specific purposes. In this scenario, operating schedule applicable under some circumstances, at the same time, may be different than other system of same size. Therefore, the implementation of DSM schemes should have flexibility in order to meet the objective of power saving and hence to improve the energy efficiency without affecting the comfort level. However, most of the traditional strategies employ specific system techniques & algorithms whereas in recent years load shifting based DSM techniques have been used for the futuristic smart grid applications.

In the commercial and residential buildings, the power consumption mainly depends upon the number of persons involved, surrounding temperature & humidity and the luminous intensity due to sun light. Therefore, the energy data of three month, in a year, is collected under three different seasonal changes i.e. January (severe cold), April (moderate) and August (severe hot), which is described in Chapter 3. This gives a clear picture of variation in load demand under moderate, comfort and severe environmental conditions. The energy data under these three conditions are averaged and the DSM schemes need to be developed for the operation of power components before energy auditing and after energy auditing.

Energy auditing strategies in co-operation with demand side management leads to huge power savings as energy consumption will be reduced and the cost of monthly electricity bills will also be reduced. This leads to enhanced energy efficiency. Enhanced energy efficiency means better utilization of electrical appliances like fans, air conditioners and tube lights. As per BEE guidelines, energy auditing techniques gives recommendations of how many fans, air conditioners and tubelights should be installed such that the energy efficiency is maintained without compromising the comfort level of the consumers.

The energy auditing strategies involves three steps:

i. Collecting the actual data of number of electrical appliances installed i.e. number of fans, air conditioners , tubelights and other electrical appliances depends upon the type of building : commercial, Industrial and residential.

ii. Calculation of recommended data of number of electrical appliances which should be installed as per BEE guidelines.

iii. Comparative analysis of both actual and recommended data which leads to power savings, reduced cost of monthly electricity bills . This results in enhancement of energy efficiency of electrical appliances used .

Hence the energy auditing strategies in co-operation with DSM techniques are very beneficial for the consumers as their comfort level is maintained along with the reduction in their monthly electricity bills.

**Table 5.1: Operating constraints of DSM**

| Components/ Schedule | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strength | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| Light | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 |
| Fan | 0 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| AC | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |

Table 5.1 describes the operating strategies for the lights, fans and ACs. The strategies are defined based upon the number of existing and proposed components in a specified area. However, these strategies can be changed as per the requirement and the comfortability when number of components in a specified area varies in practical system under different operating conditions.

## 5.3 Proposed DSM based Algorithm & its flowchart

A DSM based proposed algorithm has been developed incorporating with energy auditing strategies. Power consumption depends upon the following parameters:

- Temperature
- Humidity
- Luminous intensity
- Number of persons

The above constraints are very important and by keeping which in mind the algorithm has been proposed. Temperature, luminous intensity and number of persons are the deciding parameters of switching on/off of components. This basically prevents the wastage of energy. This is so because the power demand is directly proportional to the variations in these parameters. Power demand also varies with change in season. For example in the summer season the majority of load is drawn by fans and air conditioners whereas in winter season the majority of load is drawn by lights and water heaters. So the type of load which consumes more energy is different in different seasons. In order to address these aspects, the proposed DSM based algorithm has been developed.

The steps involved in the proposed DSM based algorithm:

**1.** Read the data for number of power components, type of rooms, time of operation, surrounding environmental conditions etc.

**2.** Analysis of data by energy auditing.

   a. List the data before auditing and after auditing
   b. Set the power raring of components used before auditing and after auditing

**3.** Define the following

   I. Variation in the strength
   II. Number of AC, fan & lights (for both before auditing and after auditing)

**4.** Set the total number of room and hours.

**5.** Define the operating strategies for Fan, light & AC.

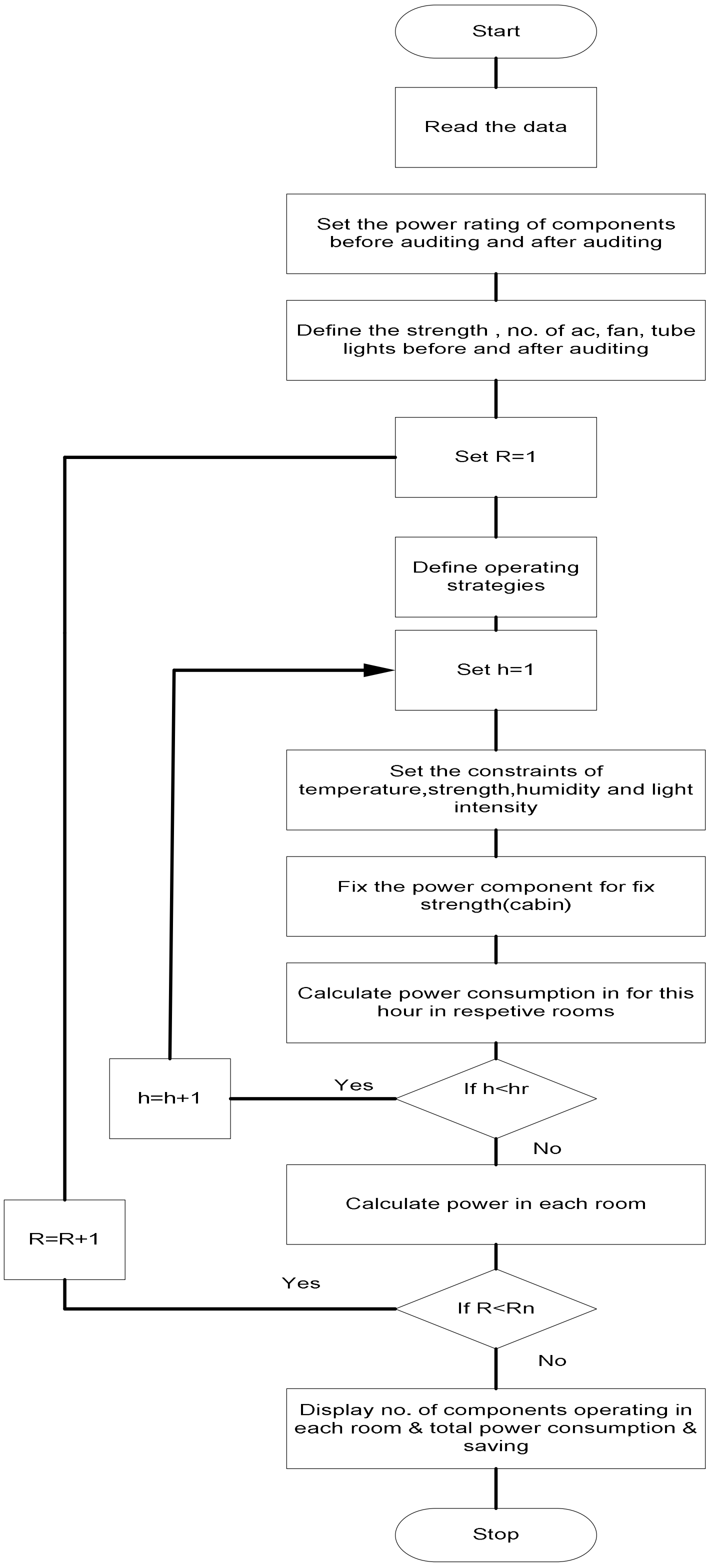


**Figure 5.1: Flowchart of DSM algorithm**

6. Identify the operating constraints i.e. temperature, maximum and minimum number of component to be operated in a specific room.
7. Calculate number of light, fan & AC to be operating for a given strategies.
8. Calculate the power consumption due to fan, light & AC in particular hours for each room.
9. Repeat step 3 to 7 for each hour.
10. Calculate power consumption & saving for each hour.
11. Calculate power consumption in each room
12. Stop & print the results.

### 5.4 Result analysis for DSM before auditing

In this work, the energy efficiency is evaluated before and after auditing. Table 5.2 to 5.4 shows the results for DSM scheme before auditing for the month of August'18, January'19 and April'19. The energy saving for the month of August and April is found to be 31.34 and 36.67kWh whereas in the month of January it is -29.24kWh. This indicates that with DSM the energy consumption has reduced in August and April whereas it has increased in the month of January'19. This is due to the fact that in January the weather conditions are very cold and the maximum light source need to be operated in order to maintain the desired level of luminance. Also, at the same time there is no scope of energy saving due to fans and ACs.

**Table 5.2 : DSM before auditing in August'18**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| **SR** | 0.4 | 0.4 | 0.3 | 0.4 | 0.1 | 0.2 | 0.1 | 0.3 |
| **Temp($^oC$)** | 27.95 | 29.00 | 29.75 | 30.875 | 30.875 | 31.17 | 30.83 | 29.88 |
| **Humidity(%)** | 79.29 | 80.67 | 77.83 | 71.25 | 72.08 | 70.54 | 72.04 | 75.38 |
| **LI (Lux)** | 18378 | 21245 | 22926 | 26550 | 25945 | 26424 | 24033 | 21999 |
| **ECTT (kWh)** | 27.09 | 52.34 | 28.01 | 23.31 | 30.57 | 30.89 | 30.71 | 26.45 |
| **ECWDSM (kWh)** | 35.67 | 33.25 | 38.54 | 31.96 | 31.00 | 37.58 | 35.08 | 37.63 |
| **Savings (kWh)** | 8.58 | -19.09 | 10.53 | 8.65 | 0.43 | 6.69 | 4.37 | 11.18 |
| **ECLT (kWh)** | 11.85 | 11.90 | 12.65 | 11.55 | 11.55 | 11.75 | 11.75 | 11.15 |
| **ECAT (kWh)** | 11.40 | 36.48 | 11.40 | 6.84 | 13.68 | 13.68 | 13.68 | 11.40 |
| **ECFT (kWh)** | 3.84 | 3.96 | 3.96 | 4.92 | 5.34 | 5.46 | 5.28 | 3.90 |

**Table 5.3: DSM before auditing in January'19**

| Parameter/Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| **SR** | 0.4 | 0.3 | 0.2 | 0.1 | 0.5 | 0.2 | 0.3 | 0.2 |
| **Temp(°C)** | 9.58 | 11.50 | 13.75 | 15.25 | 17.21 | 18.42 | 18.42 | 18.46 |
| **Humidity(%)** | 85.21 | 77.54 | 71.25 | 66.88 | 61.08 | 58.04 | 57.54 | 58.38 |
| **LI (Lux)** | 1160 | 16717 | 29437 | 34026 | 43801 | 52450 | 52602 | 46745 |
| **ECTT (kWh)** | 15.93 | 15.80 | 14.90 | 12.55 | 12.50 | 11.95 | 11.15 | 11.55 |
| **ECWDSM (kWh)** | 10.83 | 10.42 | 10.83 | 9.58 | 9.58 | 9.17 | 8.75 | 7.92 |
| **Savings (kWh)** | -5.09 | -5.38 | -4.07 | -2.97 | -2.92 | -2.78 | -2.40 | -3.63 |
| **ECLT (kWh)** | 15.93 | 15.80 | 14.90 | 12.55 | 12.50 | 11.95 | 11.15 | 11.55 |
| **ECAT (kWh)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ECFT (kWh)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 5.4: DSM before auditing in April'19**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| **SR** | 0.4 | 0.1 | 0.4 | 0.2 | 0.3 | 0.4 | 0.2 | 0.3 |
| **Temp(°C)** | 29.78 | 31.96 | 33.35 | 34.65 | 36.26 | 37.39 | 37.78 | 37.22 |
| **Humidity(%)** | 47.04 | 43.00 | 37.30 | 33.13 | 28.39 | 26.91 | 25.22 | 24.96 |
| **LI (Lux)** | 31926 | 36961 | 43475 | 5477 | 67048 | 73032 | 74209 | 70848 |
| **ECTT (kWh)** | 29.72 | 31.62 | 29.00 | 30.89 | 18.96 | 16.68 | 18.96 | 16.74 |
| **ECWDSM (kWh)** | 27.91 | 28.32 | 29.32 | 28.32 | 29.77 | 32.55 | 27.55 | 25.50 |
| **Savings (kWh)** | -1.81 | -3.30 | 0.32 | -2.57 | 10.81 | 15.87 | 8.59 | 8.76 |
| **ECLT (kWh)** | 12.20 | 12.60 | 12.50 | 11.75 | 0 | 0 | 0 | 0 |
| **ECAT (kWh)** | 13.68 | 13.68 | 11.40 | 13.68 | 13.68 | 11.40 | 13.68 | 11.40 |
| **ECFT (kWh)** | 3.84 | 5.34 | 5.10 | 5.46 | 5.28 | 5.28 | 5.28 | 5.34 |

## 5.5 Result discussion for DSM after auditing

In this section the results of DSM after auditing are discussed. IN the proposed work the DSM is implemented in two ways i.e.

a. When light source are LEDs having power rating of 13Watts.
b. When light source are CFLs having power rating of 22Watts.

### 5.5.1 DSM after auditing when light source is LEDs

Table 5.5 to 5.7 show the result of DSM after auditing in the month of August'18, January'19 and April'19 when light source is LED. The daily energy saving for the month of August and April is found to be 127.09 and 108.83kWh whereas in the month of January it is 49.52kWh. This indicates that with DSM the energy consumption has reduced significantly in the month of August and April whereas unlike, DSM before auditing the energy consumption has also reduced in the month of January as well. However, the reduction in energy consumption in January is less as compared to the August and April and this is due to the fact that in January the weather conditions are very cold and the maximum light source need to be operated in order to maintain the desired level of luminance. Also, at the same time there is no scope of energy saving due to fans and ACs.

**Table 5.5: DSM with auditing in august'18**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| **SR** | 0.4 | 0.4 | 0.3 | 0.4 | 0.1 | 0.2 | 0.1 | 0.3 |
| **Temp(°C)** | 27.95 | 29.00 | 29.75 | 30.875 | 30.875 | 31.17 | 30.83 | 29.88 |
| **Humidity(%)** | 79.29 | 80.67 | 77.83 | 71.25 | 72.08 | 70.54 | 72.04 | 75.38 |
| **LI (Lux)** | 18378 | 21245 | 22926 | 26550 | 25945 | 26424 | 24033 | 21999 |
| **ECTT (kWh)** | 15.66 | 40.38 | 15.89 | 14.76 | 17.19 | 17.10 | 17.01 | 15.63 |
| **ECWDSM (kWh)** | 35.67 | 33.25 | 38.54 | 31.96 | 31 | 37.58 | 35.08 | 37.63 |
| **Savings (kWh)** | 20.00 | -7.13 | 22.65 | 17.20 | 13.81 | 20.48 | 18.08 | 21.99 |
| **ECLT (kWh)** | 3.12 | 2.82 | 3.23 | 3.06 | 3.09 | 3.00 | 3.03 | 2.97 |
| **ECAT (kWh)** | 9.12 | 34.20 | 9.12 | 6.84 | 9.12 | 9.12 | 9.12 | 9.12 |
| **ECFT (kWh)** | 3.42 | 3.36 | 3.54 | 4.86 | 4.98 | 4.98 | 4.86 | 3.54 |

**Table 5.6 : DSM with auditing in January'19**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| **SR** | 0.4 | 0.3 | 0.2 | 0.1 | 0.5 | 0.2 | 0.3 | 0.2 |
| **Temp(°C)** | 9.58 | 11.50 | 13.75 | 15.25 | 17.21 | 18.42 | 18.42 | 18.46 |
| **Humidity(%)** | 85.21 | 77.54 | 71.25 | 66.88 | 61.08 | 58.04 | 57.54 | 58.38 |
| **LI (Lux)** | 1160 | 16717 | 29437 | 34026 | 43801 | 52450 | 52602 | 46745 |
| **ECTT (kWh)** | 3.96 | 4.16 | 3.92 | 3.38 | 3.36 | 3.00 | 2.84 | 2.96 |
| **ECWDSM (kWh)** | 10.83 | 10.42 | 10.83 | 9.58 | 9.58 | 9.17 | 8.75 | 7.92 |
| **Savings (kWh)** | 6.87 | 6.26 | 6.92 | 6.21 | 6.23 | 6.66 | 5.91 | 4.96 |
| **ECLT (kWh)** | 3.96 | 4.16 | 3.92 | 3.38 | 3.36 | 3.00 | 2.84 | 2.96 |
| **ECAT (kWh)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **ECFT (kWh)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 5.7: DSM with auditing in April'19**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| **SR** | 0.4 | 0.1 | 0.4 | 0.2 | 0.3 | 0.4 | 0.2 | 0.3 |
| **Temp(°C)** | 29.78 | 31.96 | 33.35 | 34.65 | 36.26 | 37.39 | 37.78 | 37.22 |
| **Humidity(%)** | 47.04 | 43.00 | 37.30 | 33.13 | 28.39 | 26.91 | 25.22 | 24.96 |
| **LI (Lux)** | 3192 6 | 36961 | 43475 | 5477 | 67048 | 73032 | 74209 | 70848 |
| **ECTT (kWh)** | 15.74 | 17.23 | 14.72 | 16.98 | 13.92 | 13.98 | 13.80 | 14.04 |
| **ECWDSM (kWh)** | 27.91 | 28.32 | 29.32 | 28.32 | 29.77 | 32.55 | 27.55 | 25.50 |
| **Savings (kWh)** | 12.17 | 11.09 | 14.60 | 11.34 | 15.85 | 18.57 | 13.75 | 11.46 |
| **ECLT (kWh)** | 3.14 | 3.31 | 3.14 | 3.06 | 0 | 0 | 0 | 0 |
| **ECAT (kWh)** | 9.12 | 9.12 | 6.84 | 9.12 | 9.12 | 9.12 | 9.12 | 9.12 |
| **ECFT (kWh)** | 3.48 | 4.80 | 4.74 | 4.80 | 4.80 | 4.86 | 4.68 | 4.92 |

### 5.5.2 DSM after auditing when light source is CFLs

Table 5.8 to 5.10 show the result of DSM after auditing in the month of August'18, January'19 and April'19 when light source is LED. The daily energy saving for the month of August and April is found to be 105.93 and 100.62kWh whereas in the month of January it is 22.33kWh. This indicates that with DSM the energy consumption has reduced significantly in the month of August and April whereas unlike, DSM before auditing the energy consumption has also reduced in the month of January as well. However, the reduction in energy consumption in January is less as compared to the August and April and this is due to the fact that in January the weather conditions are very cold and the maximum light source need to be operated in order to maintain the desired level of luminance. Also, at the same time there is no scope of energy saving due to fans and ACs.

**Table 5.8: DSM with auditing in august'18**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| SR | 0.4 | 0.4 | 0.3 | 0.4 | 0.1 | 0.2 | 0.1 | 0.3 |
| Temp($^oC$) | 27.95 | 29.00 | 29.75 | 30.87 | 30.875 | 31.17 | 30.83 | 29.88 |
| Humidity(%) | 79.29 | 80.67 | 77.83 | 71.25 | 72.08 | 70.54 | 72.04 | 75.38 |
| LI (Lux) | 18378 | 21245 | 22926 | 2655 | 25945 | 26424 | 24033 | 21999 |
| ECTT (kWh) | 16.46 | 43.52 | 18.89 | 17.34 | 20.22 | 19.89 | 19.87 | 18.58 |
| ECWDSM (kWh) | 35.67 | 33.25 | 38.54 | 31.96 | 31.00 | 37.58 | 35.08 | 37.63 |
| Savings (kWh) | 19.21 | -10.27 | 19.65 | 11.41 | 10.78 | 17.69 | 15.22 | 19.05 |
| ECLT (kWh) | 6.14 | 5.96 | 6.29 | 5.76 | 6.18 | 5.92 | 6.01 | 5.92 |
| ECAT (kWh) | 6.84 | 34.20 | 9.12 | 6.84 | 9.12 | 9.12 | 9.12 | 9.12 |
| ECFT (kWh) | 3.48 | 3.36 | 3.48 | 4.74 | 4.92 | 4.86 | 4.74 | 3.54 |

**Table 5.9: DSM with auditing in January'19**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| SR | | | | | | | | |
| Temp($^oC$) | 9.58 | 11.50 | 13.75 | 15.25 | 17.21 | 18.42 | 18.42 | 18.46 |
| Humidity(%) | 85.21 | 77.54 | 71.25 | 66.88 | 61.08 | 58.04 | 57.54 | 58.38 |
| LI (Lux) | 1160 | 16717 | 29437.25 | 34026.21 | 43801.04 | 52450.96 | 52602.96 | 46745.75 |
| ECTT (kWh) | 8.01 | 7.99 | 7.59 | 6.60 | 6.69 | 5.94 | 5.85 | 6.09 |
| ECWDSM (kWh) | 10.83 | 10.42 | 10.83 | 9.58 | 9.58 | 9.17 | 8.75 | 7.92 |
| Savings (kWh) | 2.83 | 2.43 | 3.24 | 2.98 | 2.89 | 3.23 | 2.89 | 1.82 |
| ECLT (kWh) | 8.01 | 7.99 | 7.59 | 6.60 | 6.69 | 5.94 | 5.85 | 6.09 |
| ECAT (kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ECFT (kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 5.10: DSM with auditing in April'19**

| Parameter/ Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
|---|---|---|---|---|---|---|---|---|
| SR | 0.4 | 0.1 | 0.4 | 0.2 | 0.3 | 0.4 | 0.2 | 0.3 |
| Temp($^{o}$C) | 29.78 | 31.96 | 33.35 | 34.65 | 36.26 | 37.39 | 37.78 | 37.22 |
| Humidity(%) | 47.04 | 43.00 | 37.30 | 33.13 | 28.39 | 26.91 | 25.22 | 24.96 |
| LI (Lux) | 31926 | 36961 | 43475 | 5477 | 67048 | 73032 | 74209 | 70848 |
| ECTT (kWh) | 18.63 | 20.48 | 15.82 | 20.16 | 13.98 | 13.98 | 13.74 | 11.82 |
| ECWDSM (kWh) | 27.91 | 28.32 | 29.32 | 28.32 | 29.77 | 32.55 | 27.55 | 25.50 |
| Savings (kWh) | 9.28 | 7.84 | 13.50 | 8.16 | 15.79 | 18.57 | 13.81 | 13.68 |
| ECLT (kWh) | 6.09 | 6.62 | 6.34 | 6.12 | 0 | 0 | 0 | 0 |
| ECAT (kWh) | 9.12 | 9.12 | 4.56 | 9.12 | 9.12 | 9.12 | 9.12 | 6.84 |
| ECFT (kWh) | 3.42 | 4.74 | 4.92 | 4.92 | 4.86 | 4.86 | 4.62 | 4.98 |

Table 5.11 shows the number of existing and proposed components before and after strategic auditing. Here, it can be noticed that the light sources are calculated when all the component are LED and CFL as shown in Part A and Part B of table 32. In Part A, there were no existing LED and all the light source need to be replaced therefore, the difference is equal to the proposed components.

**Table 5.11: Cost of components, savings and the payback period**

| Items | Existing Component | Proposed component | Extra Component Required | Labour Cost(Rs) | Accessories Cost (Rs) | Component Cost (Rs/unit) | Total Cost (Rs) | Energy Saving (kWh) | Energy Cost@7/- | Payback Period (Year) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Part A: When light source is LED** | | | | | | | | | | |
| LED | 0 | 610 | 610 | 60 | 50 | 130 | 79410 | 95.15 | 133210 | 0.60 |
| FAN | 178 | 142 | -36 | NA | NA | NA | NA | | | |
| AC1 | 39 | 17 | -22 | NA | NA | NA | NA | | | |
| AC2 | 39 | 32 | -7 | NA | NA | NA | NA | | | |
| **Part B: When light source is CFL** | | | | | | | | | | |
| CFL | 107 | 610 | 503 | 60 | 50 | 75 | 37835 | 76.29 | 106806 | 0.35 |
| FAN | 178 | 142 | -36 | NA | NA | NA | NA | | | |
| AC1 | 39 | 17 | -22 | NA | NA | NA | NA | | | |
| AC2 | 39 | 32 | -7 | NA | NA | NA | NA | | | |

On the other hand, in the proposed auditing, the number of fans and ACs are found to be extra than the required. In the analysis, it is believed that the cost of the extra components cannot be recovered and therefore, their labour cost, accessories cost and component cost is not applicable as shown in table 32 in part A and B. Further, average energy saving per day is taken and the cost of energy saving is calculated at the rate of Rs. 7 per kWh for 200 days in a year. From the results shown in Table 32, it can be observed that the simple payback period of proposed approach is 7 months (approx.) when light source is LED whereas, it is only 4 months when light source is CFL.

**Table 5.12: Room size and components before and after auditing**

| S. No. | Room No | Room size in feet | | | Before Auditing | | | After Auditing | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Length | Breadth | Height | Fan | Light | AC | Fan | Light | AC |
| 1 | D106 | 18.5 | 8.67 | 8.42 | 2 | 14 | 2 | 2 | 5 | 1 |
| 2 | D104 | 38 | 30 | 8.83 | 7 | 26 | 3 | 7 | 32 | 3 |
| 3 | D107 | 18.5 | 8.67 | 8.42 | 2 | 4 | 0 | 2 | 5 | 0 |
| 4 | D108 | 18.5 | 8.67 | 8.42 | 2 | 4 | 0 | 2 | 5 | 0 |
| 5 | D109 | 18.5 | 8.67 | 8.42 | 2 | 3 | 0 | 2 | 5 | 0 |
| 6 | D110 | 18.5 | 8.67 | 8.42 | 2 | 3 | 0 | 2 | 5 | 0 |
| 7 | D101(CAM LAB) | 29.92 | 24.42 | 9.08 | 6 | 18 | 4 | 5 | 20 | 3 |
| 8 | D102(CAD LAB -2) | 29.92 | 24.42 | 9.08 | 6 | 16 | 4 | 5 | 20 | 3 |
| 9 | D116 | 41.25 | 50.5 | 11.83 | 16 | 52 | 0 | 12 | 58 | 0 |
| 10 | D115 | 41.25 | 50.5 | 11.83 | 12 | 52 | 0 | 12 | 58 | 0 |
| 11 | Research Lab | 35 | 9.42 | 9 | 4 | 8 | 2 | 3 | 9 | 2 |
| 12 | D201 | 35.75 | 29.83 | 9.42 | 11 | 40 | 4 | 7 | 30 | 3 |
| 13 | D202 | 35.75 | 29.83 | 9.42 | 11 | 40 | 4 | 7 | 30 | 3 |
| 14 | D203 | 29.66 | 18.33 | 9.42 | 5 | 22 | 2 | 4 | 15 | 2 |
| 15 | D204 | 29.66 | 18.33 | 9.42 | 5 | 23 | 2 | 4 | 15 | 2 |
| 16 | Cabin near str. Lab | 12.75 | 12.42 | 12.42 | 1 | 4 | 1 | 2 | 5 | 1 |
| 17 | Structure Lab | 157 | 30.75 | 16.08 | 36 | 46 | 0 | 28 | 136 | 0 |
| 18 | D120 | 13 | 10 | 13.83 | 1 | 2 | 0 | 1 | 4 | 0 |
| 19 | Dr.Tapas cabin | 30.75 | 13 | 13.83 | 2 | 3 | 0 | 3 | 12 | 0 |
| 20 | D112(Lab) | 31.75 | 28.5 | 8.92 | 11 | 16 | 4 | 6 | 25 | 3 |
| 21 | Transportation Lab | 49.42 | 29 | 12.92 | 15 | 40 | 0 | 9 | 40 | 0 |
| 22 | D117 | 30.42 | 12.25 | 14.25 | 2 | 2 | 0 | 3 | 11 | 0 |
| 23 | D114 | 18.58 | 8.58 | 14.42 | 2 | 4 | 0 | 2 | 5 | 0 |
| 24 | D113 | 18.58 | 8.58 | 14.42 | 2 | 4 | 0 | 2 | 5 | 0 |
| 25 | D111(MED Office) | 18.75 | 19.83 | 9.17 | 2 | 8 | 0 | 3 | 11 | 0 |
| 26 | D123 | 13 | 10 | 13.83 | 1 | 2 | 0 | 1 | 4 | 0 |
| 27 | Dr.T.P cabin | 19.33 | 8.67 | 8.42 | 2 | 10 | 1 | 2 | 5 | 1 |
| 28 | D103 | 13 | 10 | 13.83 | 1 | 2 | 0 | 1 | 4 | 0 |
| 29 | D118 | 30.42 | 22.67 | 9.33 | 4 | 28 | 4 | 5 | 19 | 3 |
| 30 | Room near stairs | 12.75 | 12.42 | 12.42 | 1 | 8 | 0 | 2 | 5 | 0 |
| 31 | D119 | 13 | 10 | 13.83 | 1 | 8 | 1 | 1 | 4 | 1 |
| 32 | D121 | 12.83 | 12.25 | 9.42 | 1 | 8 | 0 | 2 | 5 | 0 |
| 33 | Corridor -1 | 418.08 | 11.67 | 8.83 | 0 | 10 | 0 | 0 | 10 | 0 |
| 34 | Corridor- 2 | 62.42 | 19.92 | 12.58 | 0 | 3 | 0 | 0 | 3 | 0 |

Table 5.12 gives information about the room size, components before auditing and components after applying auditing schemes. The comparative analysis as shown in this table gives clear picture that after applying auditing schemes the number of components i.e. tube lights, CFL (Single, Double), fans and ACs will be reduced and hence power consumption will be reduced which further leads to reduction in monthly electricity bills. This enhance the energy efficiency of the equipments used .

## 5.6 Conclusion

This chapter describes the energy efficiency evaluation with demand side management (DSM). This includes the operating constraints like temperature, lux, humidity and number of persons involved in the specified area. The chapter also includes the proposed DSM algorithm and its flowchart. Along with this, the result analysis without auditing and with auditing has also been described in this chapter. From the result analysis it has been observed that there is huge scope of energy savings with DSM. However, the amount of saving differ before auditing and after auditing. Here, it can be noticed that savings are more after auditing and therefore, it is recommended to perform a regular audit of the energy consumption in a commercial or residential building in order to improve the energy efficiency.

# CHAPTER 6
# CONCLUSIONS AND FUTURE SCOPE

## 6.1 Conclusion

In chapter 1, presented an extensive review of the DSM techniques for the improvement of energy efficiency in distribution systems (EEDS). From the literature it has been observed that the DSM problem is formulated by the researchers in different ways. In the problem formulation researcher have focused on the minimization of operating cost and hence to reduce the peak demand and power losses simultaneously. The reduction in peak demand ultimately improve the sustainability of smart grids by supply more number of customer from the existing network structure, i.e. without expansion. In the related literature, demand response and home energy management are considered as the major component for effective implementation of the DSM schemes. Further, DSM provides additional incentives to the end users and promotes environment friendliness because it reduces the carbon level and green-house gases emissions which are highly responsible for pollution. DSM techniques have various benchmarks to make the future smart grid more efficient which tries to maintain the level of customer comfort by keeping balance between supply and consumers.

Chapter 2 presents the mathematical formulations for the calculation of light points, diversity factor, average illumination efficacy ratio for lighting system. The various parameters like Room Index (RI), Diversity Ratio (DR), installed load Efficacy (ILE), Installed Load Efficacy Ratio (ILER) have been studied for different room in D-block at TIET. It has been observed that these parameters are the factors to define the energy efficiency in commercial building for lighting system and they need to be maintain within desirable range for better comfort and to reduce the energy bill and hence the energy consumption in a specific area.

In chapter 3, from the comparison analysis of the actual data and recommended data it is observed that along with the modifications of existing devices or by replacing them with the energy efficient devices , various energy saving opportunities can be achieved. Also, the analysis gives us complete detail of all the parameters on which energy efficiency depends.

In chapter 4, the energy efficiency evaluation of D-block of TIET has been carried out by applying various strategic auditing techniques. In this chapter, firstly the actual data of D-block of TIET has been analyzed and after that strategic auditing techniques have been applied which gives us recommended data. And later, comparative analysis has been carried out between actual data and data recommended as per strategic auditing techniques.

In chapter 5, energy efficiency evaluation has been carried out by applying various DSM techniques which are focused on the four constraints i.e. temperature, humidity, light intensity and number of peoples involved in a specified area.

### 6.2 Future Scope of the work

In the proposed work, the static characteristic of the power components are taken into consideration. This approach allows the energy consumption at full rating of the device. However, in practice, the improvement in the system voltage profile may also affect the energy consumption and hence the effectiveness of the DSM schemes. Therefore, in future a practical model of the proposed approach need to be developed and it is required to evaluate the effect of system voltage profile on energy consumption when DSM is implemented.

# LIST OF PUBLICATIONS

1. A review and research scope for energy efficiency in commercial and residential buildings with demand side management, **Accepted in IEEE conference PEEIC2019, Greater Noida.**
2. Novel approach for strategic auditing and DSM in a commercial building for energy efficiency. [**To be submitted**].

# REFERANCES


[1] T. Logenthiran, D. Srinivasan and T.Z. Shun, “Demand side management in smart grid using heuristic optimization” , IEEE Trans on Smart Grid, vol. 3 no. 3, pp.1244-1252, 2012.

[2] M. Pipattanasomporn, M. Kuzlu, and S. Rahman, “An algorithm for intelligent home energy management and demand response analysis”, IEEE Transactions on Smart Grid, vol. 3 no. 4, pp. 2166-2173, 2012.

[3] A. Mohsenian-Rad, V. Wong, J. Jatskevich, R. Schober and A. Leon-Garcia, “Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid”, IEEE Transactions on Smart Grid, vol. 1 no. 3, pp. 320–331, 2010

[4] P. Palensky and D. Dietrich, “Demand side management: demand response, intelligent energy systems, and smart loads, IEEE Transactions on industrial informatics, vol. 7 no. 3, pp.381-388, 2011.

[5] G.T Costanzo, G. Zhiu, M. F. Anjos and G. Savard, “A system architecture for autonomous demand side load management in smart buildings”, IEEE Transactions on Smart Grid, vol. 3 no. 4, pp. 2157-2165, 2012.

[6] A. Agnetis, G. D. Pascale, P. Detti and A.Vicino, “Load scheduling for household energy consumption optimization”, IEEE Transactions on Smart Grid, vol. 4 no. 4, pp. 2364–2373, 2013.

[7] Z. Zhao,W. C. Lee, Y. Shin and K. B. Song, “An optimal power scheduling method for demand response in home energy management system”, IEEE Transactions on Smart Grid, vol. 4 no. 3, pp. 1391–1400, 2013.

[8] A. Safdarian, M. Z. Degefa, M. Lehtonenand and M. Fotuhi-Firuzabad, “Distribution network reliability improvements in presence of demand response”, IET Generation, Transmission & Distribution, vol. 8 no. 12, pp. 2027-2035, 2014.

[9] M. Kuzlu, “Score-based intelligent home energy management (HEM) algorithm for demand response applications and impact of HEM operation on customer comfort”, IET Generation Transmission and Distribution, vol.9 no. 7, pp. 627-635, 2017.

[10] A. Mondal, S. Misra and M. S. Obaidat, “Distributed home energy management system with storage in smart grid using game theory”, IEEE Systems Journal, vol. 11 no. 3, pp. 1857-1866, 2015.

[11] A. S. Abdelwahed, A. H. Zekry, H.L. Zayed and A. M. Sayed, “Controlling, electricity consumption at home: Smart home”, Tenth International Conference on Computer Engineering & Systems (ICCES), IEEE, pp. 49-54, 2015.

[12] G. Tsagarakiset, R. Camilla Thomson, Adam J. Collin, Gareth P. Harrison, Aristicides E. Kiprakis and Stephen Mclaughlin, “Assessment of the cost and environmental impact of residential demand-side management”, IEEE Transaction on Industry Applications, vol. 52 no. 3, pp. 2486-2495, 2016.

[13] H. Hao, C. D. Corbin, K. Kalsi and R. G. Pratt, “Transactive control of commercial buildings for demand response”, IEEE Transactions on Power Systems, vol. 32 no. 1, pp. 774-783, 2016

[14] A. Anvari-Moghaddam, J. M. Guerrero and J. C. Vasquez, “Efficient energy management for a grid-tied residential micro grid”, IET Generation Transmission and Distribution, vol. 11 no. 11, pp. 2752-2761, 2017.

[15] Soongeol Kwon, Lewis Ntaimo and Natarajan Gautam, “Demand response in Data centres: Integration of Server provisioning and power procurement,” IEEE transactions on Smart Grid, DOI 10.1109/TSG.2018.2871125, accepted for publication.

[16] Manuel Castillo- Cagigal, Eduardo Matallanas, Estefania Caamano-Martin and Alvaro Gutierrez Martin, “Swarm Grid: Demand –Side Management with distributed energy based on multi frequency agent coordination,” Energies, 11, 2476; doi:10.3390/en11092476, 2018.

[17] A. Facchini, C. Rottondi and G. Verticale, “Evaluating the effects of social interactions on a distributed demand side management system for domestic appliances”, Energy Efficiency, Springer Netherlands, vol. 10 no. 5, pp. 1175-1188, 2017.

[18] A. Sinha, S. Neogi, R. N. Lahiri, S. Chowdhury, S. P. Chowdhury and N. Chowdhury, “Role of demand side management for power distribution utility in India”, In proc. of IEEE power and energy society general meeting, USA, July 24-29, 2011.

[19] M. Albadi and E. El-Saadany, “Demand response in electricity markets: An overview,” in Proc. Power Eng. Soc. Gen. Meet., pp. 1–5, Jun. 2007.

[20] S. Shao, T. Zhang, M. Pipattanasomporn, and S. Rahman, “Impact of TOU rates on distribution load shape in a smart grid with PHEV penetration,” in Proc. IEEE Trans. Distrib. Conf. Expo, pp. 1–6, Apr. 2010.

[21] M.A. Piette, D. Watson, N. Motegi, S. Kiliccote, and E. Linkugel, "Automated demand response strategies and commissioning commercial building controls," in Proc.14thNatl. Conf. Building Commissioning, San Francisco, CA, Apr. 2006

[22] M. A. A. Pedrasa, T. D. Spooner, and I. F. Mac Gill, "Coordinated scheduling of residential distributed energy resource to optimize smart home energy services," IEEE Trans. Smart Grid, vol. 1, no. 2, pp. 134–143, Sep. 2010

[23] M. A. A. Pedrasa, T.D. Spooner, and I. F. Mac Gill, "Scheduling of demand side resources using binary particle swarm optimization," IEEE Trans. Power Syst., vol. 24, no. 3, pp. 1173–1181, Aug. 2009

[24] C. M. Chu, T. L. Jong, and Y. W. Huang, "A direct load control of air-conditioning loads with thermal comfort control," in Proc. IEEE PES Gen. Meet., San Francisco, CA, Jun. 2005.

[25] M. Ann-Piette, G. Ghatikar, S. Kiliccote, D. Watson, E. Koch, and D. Hennage, "Design and operation of an open, interoperable automated demand response infrastructure for commercial buildings," Journal of Comput. Inf. Sci. Eng., vol. 9, pp. 1–9, Jun. 2009.

[26] M. Zhou, Y. Gao, and G. Li, "Study on improvement of available transfer capability by demand side management," in Proc. 3rd Int. Conf. Electric Utility Deregulation and Restructuring and Power Technologies, DRPT'08, pp. 545–550, 2008.

[27] C. W. Gellings, "The concept of demand-side management for electric utilities," Proc. IEEE, vol.73, no.10, pp.1468–1470, 1985.

[28] W. Qureshi, N.-K. Nair, and M. Farid, "Demand side management through efficient thermal energy storage using phase change material," in Proc. Power Eng. Conf., AUPEC'08, Australasian Universities, pp. 1–6, 2008.

[29] Hung Khanh Nguyen, Ju Bin Song, Member, IEEE, and Zhu Han, Fellow, IEEE, "Distributed Demand Side Management with Energy Storage in Smart Grid", IEEE Transactions on Parallel And Distributed Systems, vol. 26, no. 12, pp. 3346-3357, 2015.

[30] T. Handa, A. Oda, T. Tachikawa, J. Ichimura, Y. Watanabe and H. Nishi, "Knives: A distributed demand side management system—Integration with zigbee wireless sensor network and application," in Proc. 6th IEEE Conf. Ind. In format, INDIN'08, pp. 324–329, 2008.

[31] P. Du and N. Lu, "Appliance commitment for household load scheduling, "IEEE Trans. Smart Grid, vol. 2, no. 2, pp.411–419, Jun. 2011.

[32] S. Rahman and Rinaldy, “An efficient load model for analyzing demand side management impacts, ”IEEE Trans. Power Syst., vol. 8, no. 3, pp. 1219–1226, Aug. 1993.

[33] L. Chen, N. Li, L. Jiang, and S. H. Low, , A. Chakarabortty and M. Ilic, Eds., “Optimal demand response: Problem formulation and deterministic case, ” Control and Optimization Theory for Electric Smart Grids. New York: Springer-Verlag, 2011.

[34] P. Stoll, G. Bag, J. E. Y. Rossebo, L. Rizvanovic, and M. Akerholm, “Scheduling residential electric loads for green-house gas reductions,” in Proc. 2011 2nd IEEE-PES Int. Conf. Exhib. Innov. Smart Grid Technol. (ISGT Eur.), Manchester, U.K., Dec. 5–7, 2011.

[35] S. Mohagheghi, F. Yang and B. Falahati, “Impact of demand response on distribution system reliability,” Proc. IEEE Power Engineering Society General Meeting , San Diego, CA, 2011

[36] W. Saad, Z. Han, H. V. Poor and T. Basar, “Game-theoretic methods for the smart grid: An overview of microgrid systems, demand-side management, and smart grid communications,” IEEE Signal Process. Mag., vol. 29, no. 5, pp. 86–105, Sep. 2012.

[37] H. Hao, T. Middelkoop, P. Barooah and S. Meyn, “How demand response from commercial buildings will provide the regulation needs of the grid”, in Proc. Annu. Allert on Conf. Commun., Control,Comput., pp. 1908–1913, 2012.

[38] K. Margellos and S. Oren, “Capacity controlled demand side management: A stochastic pricing analysis,” IEEE Trans. Power System., vol. 31, no. 1, pp. 706–717, Jan. 2016.

[39] S. Bahrami, V. W. Wong and J. Huang, “Data center demand response in deregulated electricity markets,” IEEE Transactions on Smart Grid, 2018.

[40] F. Rahimi and A. Ipakchi, “Demand response as a market resource under the smart grid paradigm”, IEEE Trans. Smart Grid, vol. 1,no. 1, pp:82–88, 2010.

[41] R. Deng, Z. Yang, M. Y. Chow, and J. Chen, “A survey on demand response in smart grids: mathematical models and approaches,” IEEE Trans. Ind. Inform., vol.11,no. 3, pp:570–582, 2015.

[42] D.W. Bunn, “Forecasting loads and prices in competitive power markets,” Proc. IEEE, vol. 88, pp. 163–169, Feb. 2000.

[43] P. Kumar, I. Ali, Mini S. Thomas and Surjit Singh, "Imposing voltage security and network radiality for reconfiguration of distribution systems using efficient heuristic and meta-heuristic approach", IET GTD, vol. 11 no. 10, pp. 2457-2467, 2017.

[44] I. Ali, Mini S. Thomas and P. Kumar, "Energy efficient reconfiguration for practical load combination in distribution system", IET Generation, Transmission and Distribution, vol. 9 no.11, pp. 1051-1060, 2015.

[45] P. Kumar, I. Ali and Mini S. Thomas, "Energy efficiency analysis of reconfigured distribution system for practical loads", Elsevier Journal of Perspectives in Science, vol. 8, pp. 498-501, 2016.

[46] P. Kumar and S. Singh, "Reconfiguration of radial distribution system with static load models for loss minimization", International Conference on Power Electronics, Drives and Energy Systems (PEDES), IEEE, pp.1-5, 2014.

[47] P. Kumar and S. Singh, "Comprehensive stability analysis of radial distribution system with load growth", $6^{th}$ India International Conference on Power Electronics (IICPE), IEEE, pp. 1-6, 2014.

[48] http/:www. beeindia.in/Course material for Energy Auditors Examination- Bureau of Energy Efficiency, New Delhi.

## APPENDIX-A

**Table I: Monthly energy consumption for the month of August'18**

| 14-08-2018 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter/Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
| Temp(°C) | 28 | 29 | 29 | 30 | 30 | 31 | 31 | 30 |
| Humidity(%) | 90 | 86 | 85 | 83 | 81 | 79 | 77 | 78 |
| EC_FnT (kWh) | 40 | 40 | 50 | 30 | 0 | 10 | 30 | 0 |
| E_AC(kWh) | 7 | 0 | 0 | 0 | 6 | 4 | 4 | 4 |
| EC_Total (kWh) | 47 | 40 | 50 | 30 | 6 | 14 | 34 | 4 |
| LI(Lux) | 19758 | 21736 | 23018 | 25872 | 26142 | 29879 | 27628 | 28162 |
| 15-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 29 | 30 | 30 | 29 | 30 | 29 |
| Humidity(%) | 89 | 87 | 86 | 83 | 82 | 88 | 84 | 86 |
| EC_FnT (kWh) | 10 | 10 | 10 | 0 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 6 | 7 | 0 | 0 | 5 | 6 | 5 | 5 |
| EC_Total (kWh) | 16 | 17 | 10 | 0 | 15 | 16 | 15 | 15 |
| LI(Lux) | 15759 | 18769 | 19891 | 24659 | 25698 | 23977 | 27899 | 26327 |
| 16-08-2018 | | | | | | | | |
| Temp(°C) | 27 | 28 | 29 | 30 | 30 | 29 | 29 | 29 |
| Humidity(%) | 88 | 85 | 82 | 80 | 81 | 83 | 82 | 80 |
| EC_FnT (kWh) | 10 | 20 | 40 | 40 | 30 | 40 | 40 | 20 |
| E_AC(kWh) | 6 | 7 | 0 | 0 | 6 | 6 | 8 | 8 |
| EC_Total (kWh) | 16 | 27 | 40 | 40 | 36 | 46 | 48 | 28 |
| LI(Lux) | 12071 | 15436 | 18742 | 19652 | 20000 | 27896 | 26427 | 27653 |
| 17-08-2018 | | | | | | | | |
| Temp(°C) | 31 | 30 | 32 | 31 | 33 | 32 | 31 | 30 |
| Humidity(%) | 84 | 86 | 77 | 75 | 64 | 66 | 68 | 81 |
| EC_FnT (kWh) | 50 | 60 | 30 | 10 | 20 | 20 | 30 | 30 |
| E_AC(kWh) | 11 | 10 | 11 | 12 | 12 | 10 | 11 | 0 |
| EC_Total (kWh) | 61 | 70 | 41 | 22 | 32 | 30 | 41 | 30 |
| LI(Lux) | 27642 | 25798 | 27636 | 25789 | 30000 | 29699 | 28075 | 27896 |
| 18-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 28 | 29 | 27 | 28 | 29 | 28 | 27 |
| Humidity(%) | 84 | 83 | 81 | 87 | 85 | 80 | 84 | 89 |
| EC_FnT (kWh) | 20 | 20 | 0 | 10 | 0 | 10 | 10 | 10 |
| E_AC(kWh) | 2 | 0 | 0 | 2 | 1 | 2 | 0 | 0 |
| EC_Total (kWh) | 22 | 20 | 0 | 12 | 1 | 12 | 10 | 10 |
| LI(Lux) | 21564 | 24358 | 24568 | 20032 | 21243 | 23254 | 24652 | 22439 |
| 19-08-2018 | | | | | | | | |
| Temp(°C) | 30 | 31 | 31 | 33 | 32 | 31 | 31 | 30 |
| Humidity(%) | 76 | 73 | 72 | 65 | 68 | 69 | 68 | 70 |
| EC_FnT (kWh) | 10 | 0 | 10 | 10 | 10 | 0 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 0 | 10 | 15 | 10 | 0 | 10 | 10 |
| LI(Lux) | 26872 | 27634 | 26899 | 30000 | 29896 | 27995 | 26875 | 27634 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 30 | 30 | 31 | 30 | 31 | 30 |
| Humidity(%) | 85 | 84 | 82 | 81 | 78 | 79 | 75 | 76 |
| EC_FnT (kWh) | 10 | 0 | 10 | 10 | 0 | 10 | 10 | 10 |
| E_AC(kWh) | 7 | 7 | 8 | 9 | 8 | 9 | 0 | 0 |
| EC_Total (kWh) | 17 | 7 | 18 | 19 | 8 | 19 | 10 | 10 |
| LI(Lux) | 24098 | 25889 | 26763 | 27008 | 30000 | 28762 | 29251 | 27651 |
| 21-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 29 | 29 | 30 | 31 | 31 | 30 |
| Humidity(%) | 83 | 82 | 81 | 80 | 78 | 76 | 75 | 77 |
| EC_FnT (kWh) | 40 | 40 | 40 | 40 | 30 | 40 | 10 | 10 |
| E_AC(kWh) | 18 | 17 | 16 | 16 | 16 | 8 | 0 | 0 |
| EC_Total (kWh) | 58 | 57 | 56 | 56 | 46 | 48 | 10 | 10 |
| LI(Lux) | 22345 | 26542 | 23569 | 25765 | 26897 | 30000 | 27998 | 23215 |
| 22-08-2018 | | | | | | | | |
| Temp(°C) | 27 | 30 | 32 | 34 | 32 | 29 | 28 | 28 |
| Humidity(%) | 91 | 84 | 91 | 91 | 76 | 85 | 87 | 88 |
| EC_FnT (kWh) | 20 | 20 | 10 | 30 | 10 | 20 | 10 | 20 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 9 | 24 | 3 | 1 |
| EC_Total (kWh) | 20 | 20 | 10 | 30 | 19 | 44 | 13 | 21 |
| LI(Lux) | 512 | 975 | 2700 | 18760 | 12770 | 10449 | 1035 | 9474 |
| 23-08-2018 | | | | | | | | |
| Temp(°C) | 27 | 28 | 29 | 29 | 28 | 29 | 30 | 29 |
| Humidity(%) | 92 | 88 | 84 | 84 | 85 | 85 | 86 | 85 |
| EC_FnT (kWh) | 20 | 30 | 50 | 10 | 30 | 20 | 20 | 60 |
| E_AC(kWh) | 0 | 0 | 0 | 8 | 7 | 8 | 7 | 0 |
| EC_Total (kWh) | 20 | 30 | 50 | 18 | 37 | 28 | 27 | 60 |
| LI(Lux) | 19690 | 15260 | 14087 | 22452 | 30000 | 12326 | 15625 | 6772 |
| 24-08-2018 | | | | | | | | |
| Temp(°C) | 34 | 33 | 30 | 31 | 32 | 34 | 33 | 32 |
| Humidity(%) | 86 | 81 | 85 | 84 | 72 | 71 | 70 | 70 |
| EC_FnT (kWh) | 30 | 20 | 20 | 20 | 40 | 10 | 20 | 20 |
| E_AC(kWh) | 3 | 2 | 3 | 3 | 23 | 6 | 9 | 10 |
| EC_Total (kWh) | 33 | 22 | 23 | 23 | 63 | 16 | 29 | 30 |
| LI(Lux) | 18000 | 17982 | 21680 | 25638 | 30000 | 22576 | 14756 | 10692 |
| 25-08-2018 | | | | | | | | |
| Temp(°C) | 30 | 31 | 31 | 32 | 33 | 33 | 34 | 33 |
| Humidity(%) | 75 | 74 | 75 | 69 | 66 | 65 | 64 | 67 |
| EC_FnT (kWh) | 20 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| E_AC(kWh) | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| EC_Total (kWh) | 21 | 0 | 1 | 0 | 1 | 10 | 0 | 0 |
| LI(Lux) | 19924 | 17542 | 30000 | 12609 | 29987 | 28862 | 21684 | 25639 |
| 26-08-2018 | | | | | | | | |
| Temp(°C) | 27 | 32 | 33 | 32 | 33 | 32 | 34 | 34 |
| Humidity(%) | 82 | 75 | 73 | 64 | 65 | 63 | 55 | 57 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 11 | 10 | 0 |
| LI(Lux) | 12824 | 21536 | 24648 | 30000 | 30000 | 29987 | 30000 | 24977 |
| 27-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 30 | 31 | 32 | 34 | 33 | 32 |
| Humidity(%) | 81 | 76 | 75 | 76 | 73 | 72 | 73 | 72 |
| EC_FnT (kWh) | 20 | 20 | 30 | 30 | 30 | 40 | 30 | 20 |
| E_AC(kWh) | 3 | 4 | 3 | 10 | 2 | 2 | 1 | 2 |
| EC_Total (kWh) | 23 | 24 | 33 | 40 | 32 | 42 | 31 | 22 |
| LI(Lux) | 16886 | 27689 | 28865 | 29264 | 24987 | 30000 | 26728 | 20125 |
| 28-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 30 | 31 | 28 | 30 | 29 | 30 |
| Humidity(%) | 82 | 83 | 78 | 77 | 81 | 79 | 73 | 70 |
| EC_FnT (kWh) | 30 | 20 | 30 | 40 | 20 | 40 | 50 | 30 |
| E_AC(kWh) | 4 | 8 | 6 | 6 | 16 | 4 | 3 | 3 |
| EC_Total (kWh) | 34 | 28 | 36 | 46 | 36 | 44 | 53 | 33 |
| LI(Lux) | 22987 | 24000 | 27980 | 29625 | 20000 | 24569 | 17698 | 8092 |
| 29-08-2018 | | | | | | | | |
| Temp(°C) | 27 | 27 | 28 | 29 | 30 | 30 | 29 | 28 |
| Humidity(%) | 94 | 91 | 88 | 84 | 78 | 77 | 77 | 76 |
| EC_FnT (kWh) | 20 | 20 | 20 | 40 | 30 | 40 | 40 | 40 |
| E_AC(kWh) | 15 | 17 | 14 | 21 | 11 | 18 | 17 | 16 |
| EC_Total (kWh) | 35 | 37 | 34 | 61 | 41 | 58 | 57 | 56 |
| LI(Lux) | 14834 | 19788 | 30000 | 27034 | 24128 | 24512 | 24337 | 19297 |
| 30-08-2018 | | | | | | | | |
| Temp(°C) | 29 | 30 | 31 | 32 | 32 | 33 | 32 | 31 |
| Humidity(%) | 79 | 77 | 74 | 71 | 68 | 65 | 67 | 78 |
| EC_FnT (kWh) | 20 | 20 | 30 | 30 | 20 | 20 | 20 | 30 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 20 | 20 | 30 | 30 | 20 | 20 | 20 | 30 |
| LI(Lux) | 17809 | 18975 | 17232 | 30000 | 28125 | 30000 | 25292 | 29995 |
| 31-08-2018 | | | | | | | | |
| Temp(°C) | 28 | 30 | 32 | 33 | 34 | 34 | 33 | 31 |
| Humidity(%) | 82 | 76 | 69 | 65 | 61 | 58 | 60 | 75 |
| EC_FnT (kWh) | 20 | 20 | 40 | 10 | 30 | 20 | 20 | 30 |
| E_AC(kWh) | 11 | 8 | 23 | 0 | 11 | 15 | 11 | 0 |
| EC_Total (kWh) | 31 | 28 | 63 | 10 | 41 | 35 | 31 | 30 |
| LI(Lux) | 19456 | 24842 | 27272 | 28928 | 29929 | 26568 | 19596 | 26876 |
| 01-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 28 | 29 | 30 | 31 | 31 | 30 |
| Humidity(%) | 83 | 81 | 84 | 82 | 77 | 65 | 65 | 78 |
| EC_FnT (kWh) | 10 | 10 | 10 | 0 | 0 | 10 | 0 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 0 | 0 | 10 | 0 | 0 |
| LI(Lux) | 21969 | 23968 | 22692 | 24865 | 20234 | 20569 | 24820 | 23576 |
| 02-09-2018 | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Temp(°C) | 26 | 26 | 27 | 27 | 28 | 29 | 28 | 27 |
| Humidity(%) | 86 | 83 | 80 | 82 | 77 | 76 | 82 | 85 |
| EC_FnT (kWh) | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| LI(Lux) | 24169 | 24294 | 12790 | 15987 | 12219 | 14611 | 13886 | 15623 |
| 03-09-2018 | | | | | | | | |
| Temp(°C) | 26 | 26 | 27 | 28 | 27 | 27 | 28 | 27 |
| Humidity(%) | 91 | 89 | 88 | 81 | 89 | 90 | 84 | 91 |
| EC_FnT (kWh) | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 0 |
| E_AC(kWh) | 4 | 4 | 4 | 2 | 5 | 3 | 3 | 4 |
| EC_Total (kWh) | 4 | 14 | 4 | 2 | 15 | 3 | 3 | 4 |
| LI(Lux) | 14764 | 22496 | 25320 | 28247 | 25851 | 27426 | 29987 | 29014 |
| 04-09-2018 | | | | | | | | |
| Temp(°C) | 27 | 28 | 28 | 31 | 29 | 30 | 31 | 28 |
| Humidity(%) | 84 | 80 | 83 | 70 | 76 | 73 | 71 | 81 |
| EC_FnT (kWh) | 10 | 10 | 20 | 50 | 30 | 20 | 40 | 30 |
| E_AC(kWh) | 9 | 15 | 10 | 10 | 17 | 17 | 19 | 17 |
| EC_Total (kWh) | 19 | 25 | 30 | 60 | 47 | 37 | 59 | 47 |
| LI(Lux) | 20248 | 22304 | 24722 | 30000 | 28464 | 30000 | 30000 | 14927 |
| 05-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 30 | 31 | 32 | 33 | 32 | 30 |
| Humidity(%) | 79 | 74 | 69 | 67 | 63 | 55 | 66 | 70 |
| EC_FnT (kWh) | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 65 | 0 | 27 |
| EC_Total (kWh) | 30 | 30 | 30 | 30 | 30 | 95 | 30 | 67 |
| LI(Lux) | 11998 | 12245 | 20874 | 24735 | 27760 | 30000 | 24992 | 14912 |
| 06-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 30 | 31 | 31 | 30 | 33 | 33 | 32 |
| Humidity(%) | 78 | 72 | 69 | 70 | 73 | 65 | 66 | 64 |
| EC_FnT (kWh) | 30 | 20 | 40 | 40 | 20 | 20 | 30 | 30 |
| E_AC(kWh) | 22 | 14 | 21 | 24 | 19 | 21 | 20 | 21 |
| EC_Total (kWh) | 52 | 34 | 61 | 64 | 39 | 41 | 50 | 51 |
| LI(Lux) | 26720 | 28302 | 29896 | 28980 | 29948 | 30000 | 29897 | 28250 |
| 07-09-2018 | | | | | | | | |
| Temp(°C) | 26 | 27 | 27 | 33 | 28 | 28 | 29 | 30 |
| Humidity(%) | 92 | 90 | 86 | 68 | 83 | 84 | 79 | 69 |
| EC_FnT (kWh) | 30 | 30 | 40 | 20 | 40 | 20 | 40 | 30 |
| E_AC(kWh) | 21 | 21 | 21 | 19 | 20 | 20 | 18 | 13 |
| EC_Total (kWh) | 51 | 51 | 61 | 39 | 60 | 40 | 58 | 43 |
| LI(Lux) | 20892 | 26592 | 26412 | 30000 | 21971 | 23208 | 25655 | 29899 |
| 08-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 31 | 32 | 32 | 33 | 32 | 31 |
| Humidity(%) | 81 | 75 | 71 | 67 | 65 | 61 | 62 | 69 |
| EC_FnT (kWh) | 0 | 10 | 0 | 10 | 0 | 0 | 10 | 0 |
| E_AC(kWh) | 5 | 4 | 3 | 1 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 5 | 14 | 3 | 11 | 0 | 0 | 10 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LI(Lux) | 22421 | 24028 | 25699 | 28920 | 28124 | 26545 | 27819 | 19702 |
| 09-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 28 | 29 | 30 | 32 | 31 | 33 | 31 |
| Humidity(%) | 85 | 82 | 79 | 76 | 68 | 78 | 65 | 77 |
| EC_FnT (kWh) | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 0 |
| LI(Lux) | 19484 | 20022 | 22349 | 24241 | 26625 | 21290 | 26580 | 20234 |
| 10-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 30 | 30 | 31 | 32 | 32 | 31 | 31 |
| Humidity(%) | 79 | 75 | 71 | 67 | 65 | 63 | 68 | 69 |
| EC_FnT (kWh) | 40 | 20 | 50 | 10 | 20 | 30 | 40 | 30 |
| E_AC(kWh) | 16 | 15 | 16 | 17 | 10 | 15 | 15 | 16 |
| EC_Total (kWh) | 56 | 35 | 66 | 27 | 30 | 45 | 55 | 46 |
| LI(Lux) | 16265 | 22472 | 13580 | 17980 | 28908 | 27671 | 26019 | 26125 |
| 11-09-2018 | | | | | | | | |
| Temp(degree Celsius) | 28 | 30 | 31 | 33 | 33 | 32 | 31 | 30 |
| Humidity(%) | 82 | 73 | 69 | 62 | 61 | 59 | 68 | 72 |
| EC_FnT (kWh) | 40 | 30 | 40 | 20 | 10 | 30 | 30 | 30 |
| E_AC(kWh) | 18 | 19 | 19 | 15 | 14 | 16 | 15 | 16 |
| EC_Total (kWh) | 58 | 49 | 59 | 35 | 24 | 46 | 45 | 46 |
| LI(Lux) | 22987 | 23712 | 25175 | 30000 | 29580 | 28972 | 26605 | 20412 |
| 12-09-2018 | | | | | | | | |
| Temp(°C) | 27 | 28 | 30 | 30 | 33 | 33 | 32 | 30 |
| Humidity(%) | 82 | 76 | 70 | 67 | 59 | 55 | 60 | 71 |
| EC_FnT (kWh) | 40 | 30 | 30 | 30 | 20 | 40 | 30 | 13 |
| E_AC(kWh) | 22 | 21 | 25 | 14 | 0 | 26 | 16 | 12 |
| EC_Total (kWh) | 62 | 51 | 55 | 44 | 20 | 66 | 46 | 142 |
| LI(Lux) | 22525 | 21249 | 20609 | 30000 | 21513 | 29890 | 17501 | 19287 |
| 13-09-2018 | | | | | | | | |
| Temp(°C) | 28 | 29 | 30 | 31 | 32 | 33 | 32 | 30 |
| Humidity(%) | 76 | 74 | 65 | 59 | 57 | 52 | 58 | 66 |
| EC_FnT (kWh) | 30 | 30 | 20 | 20 | 10 | 20 | 30 | 30 |
| E_AC(kWh) | 23 | 21 | 15 | 11 | 15 | 19 | 17 | 7 |
| EC_Total (kWh) | 53 | 51 | 35 | 31 | 25 | 39 | 47 | 37 |
| LI(Lux) | 18920 | 23419 | 28520 | 30000 | 20012 | 29992 | 26549 | 24807 |
| 14-09-2018 | | | | | | | | |
| Temp(°C) | 27 | 29 | 30 | 32 | 33 | 32 | 31 | 30 |
| Humidity(%) | 74 | 67 | 61 | 56 | 52 | 53 | 61 | 64 |
| EC_FnT (kWh) | 30 | 20 | 20 | 10 | 10 | 20 | 30 | 30 |
| E_AC(kWh) | 10 | 11 | 10 | 0 | 12 | 10 | 0 | 11 |
| EC_Total (kWh) | 40 | 31 | 30 | 10 | 22 | 30 | 30 | 41 |
| LI(Lux) | 13925 | 23415 | 25687 | 26815 | 30000 | 25815 | 27245 | 28128 |

## APPENDIX- B

**Table II: Monthly energy consumption for the month of January'19**

| 07-01-2019 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter/Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
| Temp(°C) | 7 | 10 | 12 | 14 | 17 | 19 | 18 | 19 |
| Humidity(%) | 95 | 93 | 92 | 91 | 91 | 88 | 89 | 87 |
| EC_FnT (kWh) | 10 | 10 | 10 | 0 | 10 | 10 | 10 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 0 | 10 | 10 | 10 | 0 |
| LI(Lux) | 985 | 3610 | 4489 | 7848 | 56145 | 64592 | 58987 | 60472 |
| 08-01-2019 | | | | | | | | |
| Temp(°C) | 10 | 12 | 14 | 18 | 18 | 19 | 19 | 18 |
| Humidity(%) | 73 | 64 | 62 | 49 | 50 | 48 | 47 | 55 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 0 | 10 | 10 | 0 |
| LI(Lux) | 3384 | 3878 | 6998 | 63676 | 66968 | 69125 | 70971 | 58664 |
| 09-01-2019 | | | | | | | | |
| Temp(°C) | 11 | 13 | 15 | 16 | 18 | 20 | 19 | 18 |
| Humidity(%) | 71 | 64 | 62 | 61 | 50 | 46 | 49 | 51 |
| EC_FnT (kWh) | 10 | 10 | 10 | 0 | 10 | 0 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total(kWh) | 10 | 10 | 10 | 0 | 10 | 0 | 10 | 10 |
| LI(Lux) | 5974 | 6857 | 10945 | 11987 | 61543 | 76992 | 71284 | 58776 |
| 10-01-2019 | | | | | | | | |
| Temp(°C) | 8 | 10 | 12 | 14 | 16 | 19 | 18 | 16 |
| Humidity(%) | 83 | 77 | 66 | 61 | 60 | 48 | 49 | 59 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 0 | 10 | 10 |
| LI(Lux) | 1084 | 3494 | 4297 | 7926 | 12847 | 69052 | 59876 | 13576 |
| 11-01-2019 | | | | | | | | |
| Temp(°C) | 10 | 12 | 14 | 17 | 19 | 19 | 18 | 17 |
| Humidity(%) | 81 | 70 | 69 | 66 | 62 | 61 | 50 | 53 |
| EC_FnT (kWh) | 10 | 20 | 10 | 10 | 10 | 10 | 10 | 0 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 20 | 10 | 10 | 10 | 10 | 10 | 0 |
| LI(Lux) | 8973 | 12693 | 38654 | 73771 | 79186 | 78987 | 57374 | 51798 |
| 14-01-2019 | | | | | | | | |
| Temp(°C) | 12 | 14 | 15 | 15 | 17 | 18 | 19 | 18 |
| Humidity(%) | 63 | 50 | 45 | 46 | 43 | 41 | 40 | 42 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 15693 | 32746 | 35680 | 37235 | 39482 | 50012 | 52807 | 44217 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15-01-2019 | | | | | | | | |
| Temp(°C) | 8 | 9 | 14 | 14 | 16 | 16 | 17 | 18 |
| Humidity(%) | 82 | 80 | 53 | 54 | 51 | 50 | 48 | 47 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 8986 | 9037 | 36463 | 38609 | 45736 | 34898 | 41819 | 49672 |
| 16-01-2019 | | | | | | | | |
| Temp(°C) | 7 | 10 | 13 | 16 | 18 | 20 | 19 | 18 |
| Humidity(%) | 82 | 73 | 63 | 54 | 48 | 52 | 58 | 60 |
| EC_FnT (kWh) | 20 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 20 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 5836 | 7809 | 110996 | 37815 | 45659 | 69214 | 54298 | 42477 |
| 17-01-2019 | | | | | | | | |
| Temp(°C) | 8 | 10 | 15 | 18 | 20 | 19 | 17 | 16 |
| Humidity(%) | 95 | 74 | 63 | 54 | 48 | 52 | 58 | 60 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 15328 | 19715 | 33649 | 40897 | 48845 | 42407 | 39508 | 37092 |
| 18-01-2019 | | | | | | | | |
| Temp(°C) | 9 | 10 | 14 | 18 | 20 | 21 | 22 | 20 |
| Humidity(%) | 87 | 76 | 64 | 57 | 50 | 49 | 47 | 51 |
| EC_FnT (kWh) | 10 | 10 | 20 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 20 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 8979 | 9824 | 29585 | 38129 | 41494 | 46276 | 59609 | 40981 |
| 21-01-2019 | | | | | | | | |
| Temp(°C) | 11 | 13 | 15 | 17 | 19 | 21 | 20 | 19 |
| Humidity(%) | 92 | 90 | 88 | 76 | 73 | 61 | 64 | 66 |
| EC_FnT (kWh) | 10 | 20 | | 20 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 20 | 10 | 20 | 10 | 10 | 10 | 10 |
| LI(Lux) | 8764 | 12902 | 25649 | 31784 | 44096 | 59318 | 55791 | 49898 |
| 22-01-2019 | | | | | | | | |
| Temp(°C) | 11 | 13 | 14 | 13 | 15 | 15 | 13 | 14 |
| Humidity(%) | 94 | 92 | 90 | 91 | 87 | 86 | 89 | 87 |
| EC_FnT (kWh) | 10 | 10 | 10 | 20 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 20 | 10 | 10 | 10 | 10 |
| LI(Lux) | 7358 | 15817 | 26349 | 35861 | 45092 | 67874 | 84963 | 51461 |
| 23-01-2019 | | | | | | | | |
| Temp(°C) | 7 | | | 13 | 18 | 20 | 20 | 14 |
| Humidity(%) | 93 | 11 | 12 | 80 | 64 | 60 | 58 | 74 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 16305 | 18549 | 30825 | 35497 | 45789 | 59361 | 43569 | 40836 |
| 24-01-2019 | | | | | | | | |
| Temp(°C) | 7 | 10 | 12 | 14 | 14 | 16 | 17 | 19 |
| Humidity(%) | 92 | 85 | 80 | 78 | 79 | 74 | 68 | 50 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 7982 | 19650 | 34548 | 37937 | 39874 | 43643 | 47804 | 56369 |
| 25-01-2019 | | | | | | | | |
| Temp(°C) | 8 | 10 | 12 | 14 | 16 | 17 | 16 | 17 |
| Humidity(%) | 94 | 91 | 77 | 64 | 55 | 52 | 59 | 53 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 0 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 0 | 10 |
| LI(Lux) | 16394 | 19736 | 23549 | 39870 | 44609 | 56371 | 53725 | 48987 |
| 28-01-2019 | | | | | | | | |
| Temp(°C) | 8 | 10 | 12 | 15 | 17 | 18 | 18 | 19 |
| Humidity(%) | 84 | 68 | 59 | 48 | 46 | 39 | 42 | 38 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 18948 | 23509 | 25263 | 29589 | 40268 | 49672 | 52894 | 56721 |
| 29-01-2019 | | | | | | | | |
| Temp(°C) | 7 | 8 | 12 | 14 | 18 | 19 | 20 | 18 |
| Humidity(%) | 89 | 72 | 59 | 49 | 39 | 38 | 36 | 47 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 0 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 0 | 10 |
| LI(Lux) | 17659 | 21473 | 26761 | 28982 | 41816 | 49968 | 56793 | 53027 |
| 30-01-2019 | | | | | | | | |
| Temp(°C) | 8 | 11 | 13 | 15 | 15 | 18 | 18 | 17 |
| Humidity(%) | 74 | 72 | 63 | 55 | 54 | 50 | 48 | 51 |
| EC_FnT (kWh) | 10 | 0 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 0 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 14627 | 19577 | 25269 | 28315 | 31426 | 37906 | 39204 | 42192 |
| 31-01-2019 | | | | | | | | |
| Temp(°C) | 11 | 11 | 14 | 14 | 17 | 18 | 18 | 17 |
| Humidity(%) | 73 | 70 | 81 | 80 | 65 | 58 | 57 | 64 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 15749 | 18677 | 28902 | 29864 | 34369 | 38199 | 43284 | 40244 |
| 01-02-2019 | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Temp(°C) | 13 | 13 | 14 | 15 | 16 | 15 | 18 | 18 |
| Humidity(%) | 76 | 75 | 70 | 67 | 63 | 68 | 59 | 55 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 17579 | 25772 | 29826 | 32301 | 38665 | 33087 | 42266 | 45596 |
| 04-02-2019 | | | | | | | | |
| Temp(°C) | 10 | 12 | 14 | 11 | 15 | 17 | 19 | 21 |
| Humidity(%) | 97 | 81 | 73 | 92 | 73 | 65 | 63 | 59 |
| EC_FnT (kWh) | 20 | 10 | 20 | 0 | 10 | 10 | 0 | 0 |
| EC_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 20 | 10 | 20 | 0 | 10 | 10 | 10 | 10 |
| LI(Lux) | 9293 | 18164 | 26753 | 23599 | 30284 | 37633 | 46714 | 49689 |
| 05-02-2019 | | | | | | | | |
| Temp(°C) | 11 | 14 | 15 | 17 | 18 | 20 | 23 | 23 |
| Humidity(%) | 87 | 83 | 82 | 77 | 66 | 62 | 48 | 47 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| EC_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 19736 | 28491 | 32984 | 36959 | 44717 | 48290 | 52173 | 56810 |
| 06-02-2019 | | | | | | | | |
| Temp(°C) | 13 | 15 | 17 | 18 | 20 | 21 | 22 | 21 |
| Humidity(%) | 93 | 81 | 76 | 71 | 66 | 63 | 62 | 63 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| EC_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 18259 | 29369 | 34842 | 42550 | 45274 | 47298 | 49889 | 43697 |
| 07-02-2019 | | | | | | | | |
| Temp(°C) | 15 | 15 | 16 | 16 | 16 | 17 | 15 | 16 |
| Humidity(%) | 95 | 92 | 89 | 84 | 83 | 82 | 93 | 82 |
| EC_FnT (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |
| E_AC(kWh) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EC_Total (kWh) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| LI(Lux) | 14572 | 19869 | 23218 | 25628 | 27041 | 28648 | 26869 | 28648 |

# Appendix- C

**Table III: Monthly energy consumption for the month of April'19**

| 08-04-2019 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter/Time (AM/PM) | 9:00-10:00 | 10:00-11:00 | 11:00-12:00 | 12:00-1:00 | 1:00-2:00 | 2:00-3:00 | 3:00-4:00 | 4:00-5:00 |
| Temp(°C) | 25 | 27 | 28 | 30 | 33 | 36 | 36 | 35 |
| Humidity(%) | 69 | 60 | 50 | 42 | 41 | 40 | 37 | 38 |
| EC_FnT (kWh) | 1010 | 1010 | 1020 | 1020 | 1020 | | 10 | 10 |
| E_AC(kWh) | 4 | 3 | 4 | 4 | 3 | 5 | 5 | 5 |
| EC_Total (kWh) | 14 | 13 | 24 | 24 | 23 | 15 | 15 | 15 |
| LI(Lux) | 29984 | 36569 | 38742 | 43628 | 56741 | 58262 | 67675 | 63108 |
| 09-04-2019 | | | | | | | | |
| Temp(°C) | 25 | 28 | 34 | 35 | 35 | 36 | 36 | 35 |
| Humidity(%) | 57 | 52 | 48 | 39 | 33 | 31 | 29 | 27 |
| EC_FnT (kWh) | 20 | 20 | 10 | 20 | 20 | 20 | 10 | 10 |
| E_AC(kWh) | 7 | 8 | 3 | 3 | 5 | 4 | 4 | 4 |
| EC_Total (kWh) | 27 | 28 | 13 | 23 | 25 | 24 | 14 | 14 |
| LI(Lux) | 27649 | 38643 | 44216 | 64746 | 68492 | 76865 | 79089 | 70464 |
| 10-04-2019 | | | | | | | | |
| Temp(°C) | 26 | 30 | 32 | 34 | 36 | 38 | 39 | 37 |
| Humidity(%) | 53 | 50 | 43 | 37 | 31 | 29 | 25 | 26 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 20 | 30 | 20 | 10 |
| E_AC(kWh) | 4 | 6 | 6 | 7 | 7 | 9 | 8 | 8 |
| EC_Total (kWh) | 24 | 26 | 26 | 27 | 27 | 39 | 28 | 18 |
| LI(Lux) | 31456 | 39672 | 48327 | 69482 | 74568 | 78585 | 87648 | 80327 |
| 11-04-2019 | | | | | | | | |
| Temp(°C) | 27 | 29 | 32 | 35 | 37 | 38 | 39 | 38 |
| Humidity(%) | 57 | 49 | 32 | 22 | 26 | 23 | 17 | 20 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 20 | 30 | 20 | 20 |
| E_AC(kWh) | 7 | 7 | 8 | 6 | 6 | 13 | 13 | 13 |
| EC_Total (kWh) | 27 | 27 | 28 | 26 | 26 | 43 | 33 | 33 |
| LI(Lux) | 33453 | 35794 | 49688 | 58421 | 71908 | 77477 | 89987 | 83461 |
| 12-04-2019 | | | | | | | | |
| Temp(°C) | 27 | 28 | 30 | 32 | 34 | 35 | 36 | 38 |
| Humidity(%) | 45 | 40 | 35 | 35 | 34 | 32 | 30 | 25 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 20 |
| E_AC(kWh) | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| EC_Total (kWh) | 27 | 27 | 27 | 27 | 27 | 27 | 37 | 27 |
| LI(Lux) | 27588 | 32285 | 39462 | 44987 | 53829 | 67208 | 72045 | 80379 |
| 15-04-2019 | | | | | | | | |
| Temp(°C) | 30 | 37 | 38 | 37 | 38 | 39 | 41 | 38 |
| Humidity(%) | 59 | 48 | 41 | 43 | 30 | 26 | 15 | 27 |
| EC_FnT (kWh) | 30 | 30 | 20 | 20 | 30 | 30 | 20 | 30 |
| E_AC(kWh) | 5 | 5 | 9 | 8 | 9 | 10 | 9 | 6 |
| EC_Total (kWh) | 35 | 35 | 29 | 28 | 39 | 40 | 29 | 36 |
| LI(Lux) | 36209 | 44682 | 68508 | 65869 | 79776 | 83692 | 97378 | 82062 |

| 16-04-2019 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Temp(°C) | 21 | 25 | 27 | 28 | 29 | 29 | 28 | 27 |
| Humidity(%) | 83 | 88 | 84 | 82 | 80 | 79 | 81 | 83 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 10 | 20 | 20 | 20 |
| E_AC(kWh) | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 3 |
| EC_Total (kWh) | 24 | 24 | 24 | 23 | 13 | 24 | 24 | 23 |
| LI(Lux) | 24393 | 32658 | 34213 | 36918 | 39460 | 41268 | 36489 | 35708 |
| 17-04-2019 | | | | | | | | |
| Temp(°C) | 21 | 20 | 20 | 21 | 23 | 23 | 25 | 27 |
| Humidity(%) | 83 | 89 | 86 | 78 | 66 | 77 | 72 | 58 |
| EC_FnT (kWh) | 30 | 20 | 20 | 20 | 10 | 20 | 20 | 10 |
| E_AC(kWh) | 3 | 3 | 11 | 15 | 13 | 12 | 9 | 9 |
| EC_Total (kWh) | 33 | 23 | 31 | 35 | 23 | 32 | 29 | 19 |
| LI(Lux) | 33737 | 30260 | 37439 | 42646 | 45678 | 48947 | 50418 | 53690 |
| 18-04-2019 | | | | | | | | |
| Temp(°C) | 22 | 24 | 25 | 26 | 27 | 28 | 29 | 29 |
| Humidity(%) | 80 | 67 | 63 | 59 | 44 | 40 | 36 | 34 |
| EC_FnT (kWh) | 10 | 10 | 10 | 20 | 10 | 10 | 20 | 20 |
| E_AC(kWh) | 2 | 2 | 2 | 3 | 3 | 4 | 6 | 5 |
| EC_Total (kWh) | 12 | 12 | 12 | 23 | 13 | 14 | 26 | 25 |
| LI(Lux) | 28873 | 33594 | 38361 | 39994 | 43627 | 45874 | 54689 | 58047 |
| 19-04-2019 | | | | | | | | |
| Temp(°C) | 25 | 26 | 27 | 30 | 32 | 33 | 33 | 32 |
| Humidity(%) | 61 | 53 | 48 | 33 | 31 | 29 | 27 | 29 |
| EC_FnT (kWh) | 20 | 20 | 10 | 10 | 20 | 10 | 10 | 10 |
| E_AC(kWh) | 7 | 8 | 4 | 2 | 8 | 6 | 10 | 9 |
| EC_Total (kWh) | 27 | 28 | 14 | 12 | 28 | 16 | 20 | 19 |
| LI(Lux) | 33891 | 37542 | 42803 | 47770 | 49901 | 56683 | 64789 | 58874 |
| 22-01-2019 | | | | | | | | |
| Temp(°C) | 30 | 32 | 34 | 35 | 37 | 38 | 37 | 36 |
| Humidity(%) | 35 | 33 | 31 | 30 | 26 | 24 | 19 | 21 |
| EC_FnT (kWh) | 20 | 20 | 20 | 10 | 20 | 20 | 20 | 20 |
| E_AC(kWh) | 11 | 11 | 10 | 0 | 5 | 10 | 10 | 7 |
| EC_Total (kWh) | 31 | 31 | 30 | 10 | 25 | 30 | 30 | 27 |
| LI(Lux) | 36393 | 38957 | 53027 | 64798 | 73215 | 78936 | 84903 | 64866 |
| 23-04-2019 | | | | | | | | |
| Temp(°C) | 34 | 35 | 36 | 36 | 38 | 38 | 39 | 39 |
| Humidity(%) | 44 | 41 | 38 | 34 | 27 | 26 | 25 | 23 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 30 | 20 | 20 | 20 |
| E_AC(kWh) | 10 | 12 | 14 | 12 | 12 | 12 | 11 | 13 |
| EC_Total (kWh) | 30 | 32 | 34 | 32 | 42 | 32 | 31 | 33 |
| LI(Lux) | 39683 | 43549 | 41651 | 67800 | 79448 | 78346 | 86464 | 84107 |
| 24-04-2019 | | | | | | | | |
| Temp(°C) | 34 | 35 | 36 | 36 | 38 | 40 | 39 | 38 |
| Humidity(%) | 52 | 47 | 30 | 29 | 25 | 26 | 28 | 29 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 30 | 20 | 10 | 20 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| E_AC(kWh) | 12 | 12 | 11 | 8 | 8 | 9 | 12 | 9 |
| EC_Total (kWh) | 32 | 32 | 31 | 28 | 38 | 29 | 22 | 29 |
| LI(Lux) | 39900 | 45378 | 47223 | 50377 | 73327 | 89364 | 15708 | 20649 |
| 25-04-2019 | | | | | | | | |
| Temp(°C) | 34 | 36 | 37 | 38 | 39 | 40 | 41 | 39 |
| Humidity(%) | 50 | 41 | 39 | 36 | 30 | 24 | 22 | 24 |
| EC_FnT (kWh) | 20 | 20 | 30 | 20 | 30 | 30 | 20 | 30 |
| E_AC(kWh) | 0 | 9 | 9 | 8 | 9 | 16 | 11 | 5 |
| EC_Total (kWh) | 20 | 29 | 39 | 28 | 39 | 46 | 31 | 35 |
| LI(Lux) | 30659 | 35223 | 47679 | 69998 | 73439 | 87711 | 87899 | 71316 |
| 26-04-2019 | | | | | | | | |
| Temp(°C) | 36 | 37 | 37 | 38 | 40 | 41 | 42 | 40 |
| Humidity(%) | 42 | 40 | 31 | 28 | 16 | 15 | 15 | 16 |
| EC_FnT (kWh) | 20 | 20 | 20 | 40 | 20 | 30 | 20 | 20 |
| E_AC(kWh) | 7 | 8 | 7 | 9 | 10 | 11 | 11 | 12 |
| EC_Total (kWh) | 27 | 28 | 27 | 49 | 30 | 41 | 31 | 32 |
| LI(Lux) | 34432 | 38261 | 42559 | 54377 | 82236 | 83059 | 84392 | 78568 |
| 29-04-2019 | | | | | | | | |
| Temp(°C) | 35 | 36 | 37 | 37 | 38 | 39 | 40 | 40 |
| Humidity(%) | 31 | 29 | 20 | 18 | 14 | 12 | 11 | 9 |
| EC_FnT (kWh) | 30 | 30 | 30 | 30 | 30 | 30 | 20 | 10 |
| E_AC(kWh) | 9 | 12 | 12 | 3 | 13 | 11 | 13 | 12 |
| EC_Total (kWh) | 39 | 42 | 42 | 33 | 43 | 41 | 33 | 22 |
| LI(Lux) | 32332 | 36458 | 48754 | 49909 | 56783 | 68434 | 74799 | 81028 |
| 30-04-2019 | | | | | | | | |
| Temp(°C) | 34 | 35 | 36 | 39 | 40 | 41 | 41 | 42 |
| Humidity(%) | 18 | 16 | 14 | 13 | 12 | 11 | 10 | 9 |
| EC_FnT (kWh) | 20 | 30 | 30 | 20 | 20 | 40 | 20 | 20 |
| E_AC(kWh) | 13 | 12 | 14 | 14 | 9 | 6 | 0 | 5 |
| EC_Total (kWh) | 33 | 42 | 44 | 34 | 29 | 46 | 20 | 25 |
| LI(Lux) | 32351 | 34619 | 36226 | 65217 | 80600 | 82329 | 83979 | 85309 |
| 01-05-2019 | | | | | | | | |
| Temp(°C) | 31 | 34 | 36 | 38 | 41 | 42 | 43 | 44 |
| Humidity(%) | 30 | 23 | 20 | 16 | 13 | 11 | 10 | 7 |
| EC_FnT (kWh) | 30 | 20 | 30 | 30 | 20 | 20 | 30 | 20 |
| E_AC(kWh) | 7 | 10 | 5 | 5 | 10 | 11 | 11 | 8 |
| EC_Total (kWh) | 37 | 30 | 35 | 35 | 30 | 31 | 41 | 28 |
| LI(Lux) | 22569 | 29645 | 33919 | 54698 | 76897 | 83972 | 87109 | 89999 |
| 02-05-2019 | | | | | | | | |
| Temp(°C) | 35 | 38 | 37 | 38 | 36 | 38 | 39 | 38 |
| Humidity(%) | 21 | 17 | 19 | 18 | 19 | 15 | 13 | 14 |
| EC_FnT (kWh) | 20 | 30 | 30 | 20 | 30 | 30 | 30 | 20 |
| E_AC(kWh) | 11 | 10 | 22 | 13 | 16 | 18 | 16 | 19 |
| EC_Total (kWh) | 31 | 40 | 52 | 33 | 46 | 48 | 46 | 39 |
| LI(Lux) | 34689 | 47899 | 46023 | 48452 | 42379 | 49972 | 57661 | 53210 |
| 03-05-2019 | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Temp(°C) | 33 | 36 | 37 | 38 | 38 | 39 | 39 | 40 |
| Humidity(%) | 34 | 31 | 28 | 22 | 20 | 18 | 16 | 13 |
| EC_FnT (kWh) | 20 | 20 | 20 | 20 | 20 | 30 | 20 | 20 |
| E_AC(kWh) | 14 | 15 | 15 | 14 | 13 | 13 | 14 | 14 |
| EC_Total (kWh) | 34 | 35 | 35 | 34 | 33 | 43 | 34 | 34 |
| LI(Lux) | 30557 | 32393 | 35622 | 47997 | 78836 | 87379 | 83904 | 85226 |
| 06-05-2018 | | | | | | | | |
| Temp(°C) | 32 | 34 | 36 | 37 | 42 | 44 | 40 | 41 |
| Humidity(%) | 31 | 25 | 18 | 13 | 7 | 7 | 22 | 18 |
| EC_FnT (kWh) | 20 | 10 | 20 | 20 | 20 | 20 | 20 | 10 |
| E_AC(kWh) | 4 | 4 | 9 | 8 | 7 | 6 | 10 | 9 |
| EC_Total (kWh) | 24 | 14 | 29 | 28 | 27 | 26 | 30 | 19 |
| LI(Lux) | 27760 | 32393 | 35622 | 47997 | 78336 | 87379 | 83904 | 85226 |
| 07-05-2019 | | | | | | | | |
| Temp(°C) | 35 | 36 | 37 | 39 | 41 | 42 | 43 | 42 |
| Humidity(%) | 19 | 25 | 24 | 22 | 17 | 14 | 11 | 15 |
| EC_FnT (kWh) | 20 | 20 | 30 | 20 | 20 | 30 | 20 | 20 |
| E_AC(kWh) | 11 | 11 | 12 | 3 | 12 | 12 | 13 | 14 |
| EC_Total (kWh) | 31 | 31 | 42 | 23 | 32 | 42 | 33 | 34 |
| LI(Lux) | 35487 | 37859 | 43621 | 63799 | 79986 | 84170 | 86491 | 83211 |
| 08-05-2019 | | | | | | | | |
| Temp(°C) | 33 | 37 | 38 | 40 | 42 | 43 | 44 | 41 |
| Humidity(%) | 28 | 25 | 16 | 13 | 11 | 10 | 9 | 9 |
| EC_FnT (kWh) | 20 | 20 | 30 | 20 | 20 | 30 | 20 | 20 |
| E_AC(kWh) | 11 | 10 | 6 | 7 | 18 | 18 | 8 | 8 |
| EC_Total (kWh) | 31 | 30 | 36 | 27 | 38 | 48 | 28 | 28 |
| LI(Lux) | 30257 | 35785 | 46260 | 59992 | 82657 | 83835 | 89394 | 80689 |

Gagan_Thesis_Mtech

ORIGINALITY REPORT

| 8% | 6% | 3% | 6% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | www.energymanagertraining.com<br>Internet Source | 4% |
| 2 | usa-site.powerknot.co.uk<br>Internet Source | <1% |
| 3 | infojanala.blogspot.com<br>Internet Source | <1% |
| 4 | sherrygarris.homesandland.com<br>Internet Source | <1% |
| 5 | Soongeol Kwon, Lewis Ntaimo, Natarajan Gautam. "Demand Response in Data Centers: Integration of Server Provisioning and Power Procurement", IEEE Transactions on Smart Grid, 2018<br>Publication | <1% |
| 6 | Kuzlu, Murat. "Score-based intelligent home energy management (HEM) algorithm for demand response applications and impact of HEM operation on customer comfort", IET Generation Transmission & Distribution, 2015.<br>Publication | <1% |

| | | |
|---|---|---|
| 7 | Submitted to Somerset College<br>Student Paper | <1 % |
| 8 | Submitted to Central Queensland University<br>Student Paper | <1 % |
| 9 | "Plug In Electric Vehicles in Smart Grids", Springer Nature, 2015<br>Publication | <1 % |
| 10 | Piyush Jain, S. C. Solanki, Ravi Nagaich, Pavan Jain. "PERFORMANCE OF LIGHTING SYSTEM OF A PHARMACEUTICAL INDUSTRY", Industrial Engineering Journal, 2018<br>Publication | <1 % |
| 11 | P. Hanselaer, C. Lootens, W.R. Ryckaert, G. Deconinck, P. Rombauts. "Power density targets for efficient lighting of interior task areas", Lighting Research & Technology, 2016<br>Publication | <1 % |
| 12 | uu.diva-portal.org<br>Internet Source | <1 % |
| 13 | www.ee.ucr.edu<br>Internet Source | <1 % |
| 14 | B. Priya Esther, K. Sathish Kumar. "A survey on residential Demand Side Management architecture, approaches, optimization models and methods", Renewable and Sustainable | <1 % |